To Investigate the Electrical Impedance of the Aloe Barbadensis Miller Leaves

Sanjeev Kumar Sharma, Randhir Singh, Parveen Lehana

Abstract— ***The growth and health status of plants can be accessed from the electrical properties of its limbs such as leaves and stem. Present investigations were carried out to study the electrical impedance of Aloe Barbadensis Miller (Aloe-vera) leaves for investigating the effect of external ac current on its tissues Impedance was estimated over the frequency ranging from 500 Hz to 20 kHz. Aloe-vera plant has been chosen because of its extensive applications in dermatology. It is also known as "Lilly of Desert". The leaves of Aloe-vera contain a soothing thick sap that is useful for treatment and curing of wounds and diseases. The estimated impedance of the leaves was found to be a function of applied ac frequency across the leaves. The impedance of the leaf tissue decreases with the increase in frequencies of input signal. This may be due to change of dielectric properties of Aloe-vera tissues indicating a mechanism of evaluating the health status of Aloe-vera by estimating its electrical impedance***

Index Terms— ***Aloe-vera, Thigmomophogenisis, Agri-wave technology, AC signal impedance, CAM.***

I. INTRODUCTION

Living beings, whether they are animals or plants, have the ability to sense specific external and internal signals and react to them for improving their continued existence and reproductive successes. Like animals, plants also have cellular receptors which they use to detect changes in their surroundings. The changes are of various types and vary from plant to plant. For example the concentration of the growth hormones increases in response to an injury from a caterpillar munching on leaves or reduction in the day length as winter approaches. In order to sense the internal or external stimuli to elicit a physiological response, certain cells in the organism must possess an appropriate receptor. Upon receiving a stimulus, a receptor in plants initiates an explicit series of biochemical steps, called signal transduction pathway, in which receptors detect the signals. As a result cells undergo changes in shape or size in response to the stimulus [1]. Plants also show thigmomophogenisis, which is the process in which growth or development of plants can be affected in response to mechanical stimulation. The various examples of mechanical stimulations are non-injurious touch, wind, and vibration [2]. Plants are also found sound or vibration sensitive. The study of effects of sound and vibrations on plants is Agri-wave technology. The basic idea behind Agri-wave technology is to improve the yield and quality of plants such as vegetables, flowers, and fruit trees by spreading sound waves of certain frequencies and spraying a compound microelement fertilizer on the leaves. The application of Agri-wave technology on tomatoes remarkably stimulates growth of their seedlings [3]. In [4], the effect of 40-120 Hz vibrational frequencies on the seed germination of Arabidopsis thaliana was investigated by keeping the amplitude of the waves smaller than 42 mm. The rate of increase in germination appeared to depend upon the frequency and amplitude of the vibration. Hence, the growth of plants can be significantly affected using music as stimulators. The effect of sound, vibrations, and music on plants may be due to interaction of genetic structures in the cells, cavitation phenomenon due presence of capillaries in the plants and the soil, effect of pressure variations on movement of molecules affecting diffusion processes, and resonance of tissues in the plants. The effect of sounds on plants apparently depends on frequency, intensity, and exposure time [5], [6].

Plants are also sensitive to light stimuli. For example, sunflower faces toward sunlight and some flower open and close in response to light (400 to 700 nm). For green plants light acts as both a source of energy and a source of information. It is source of energy for photosynthesis, and source of information for photoperiodism (night/day length), phototropism (light direction) and photomorphogenesis (light quantity and quality). The main informational units in plants are photoreceptors and can be classified into three group's phytochomes, blue/UV-A, and UV-B photoreceptors [7]. The rate of photosynthesis and respiration can be affected by number of other environmental factors also such as concentration of O2, CO2, temperature, water, and nutrient supply [8].

Electrical conduction varies from plant to plant [9],[10]. Plants comprises of complex and well-ordered both conductive and insulative elements. As a result the resistance of different plant tissues is not purely ohmnic but depends upon the frequency. As the electrical impedance of plant tissues varies significantly from plant to plant and hence, a comprehensible idea of plant tissue electrical properties such as their electrical impedance is needed to be estimated for the assessment of their health status. The objective of this paper is to investigate the effect of ac frequencies on the electrical impedance of Aloe-vera leaves for characterizing its health status. The Aloe-vera has been chosen because of its important applications in dermatology. The detail of Aloe-vera plant is presented in the following section. The methodology is given is Section III and results along with the conclusions in Section IV.

II. ALOE-VERA

Aloe-vera is used in medicine and commercial cosmetology products in a large number of countries.

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The knowledge about the plant's physiological, growth, and yield responses under different conditions of stimuli is very limited. The plant has a crassulacean acid metabolism (CAM) that allows water conservation within the tissue, and therefore, resistance to high water stress [11]. Today Aloe-vera gel is an active ingredient in large numbers of skin lotions, sun blocks, and cosmetics [12]. The use of gel use in cosmetics has a function similar to anti-aging effects of vitamin A derivatives [13].The gel or mucilage obtained from the flesh of the leaf contains compounds some amount of bitter latex extract came from leaf lining [14]. Aloe gel is 99% water with a pH of 4.5 and is a common ingredient in many non-prescription skin salves. The gel contains an important component like polysaccharide, glucomannan etc. It acts as moisturizer, which accounts for its use in many cosmetics [15].

A. Anatomy of Aloe leaf

The plant has triangular, fleshy leaves with serrated edges, yellow tubular flowers, and fruits that contain numerous seeds. Each leaf is composed of three layers. These are shown in Fig. 1.

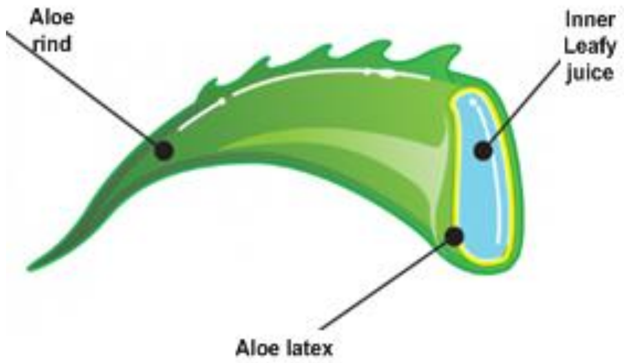

Fig. 1. Anatomical component of Aloe leaf.

B. Aloe Rind

It is the protective, green, outer covering of leaf and have no significant nutritional value (Fig. 2).

Fig. 2. Aloe rind.

C. Aloe Latex

It is a bitter, yellowish, sap like fluid which has strong odour and flows in between the leaf rind and the inner fleshy part of the leaf. Aloe latex is not suggested for consumption. It is shown in Fig. 3.

Fig. 3. Aloe latex.

D. Inner leafy juice

It is clear, inner, fleshy, portion of the leaf. It is rich in nutrients and very healthy for both internal and external consumption. It is shown in Fig. 4.

Fig. 4. Inner gel.

The inner clear gel contains 99% water and the rest is made of glucomannans, amino acids, lipids, sterols, and vitamins.

Aloe-vera gel has been used as a vigorous ingredient in large number of skin lotions, sun blocks, cosmetics, and medicines Its use in cosmetics has been inspired because of its anti-aging effects similar to vitamin A derivatives. In treating X-ray burns Aloe-vera gained popularity in the United States in the 1930's. Moreover, the Aloe gel has been extensively used in gastrointestinal disorders, including peptic ulcer, and its clinical usefulness. Today two species are grown commercially, namely Aloe Barbadensis Miller and Aloe Arborescence. Annually, in the spring, Aloe-vera produces yellow flowers. Aloe plant is grown in warm tropical areas and cannot survive freezing temperature.

III. METHODOLOGY

The investigations were carried out on the leaves of the Aloe-vera plant to study the effect of ac frequencies on the electrical impedance of the leaves. The plant was grown in a pot containing fertile soil under natural environmental conditions. Alternating stimulation was applied using a function generator.

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The experimental setup may be understood by the Fig. 5 and Fig. 6, respectively.

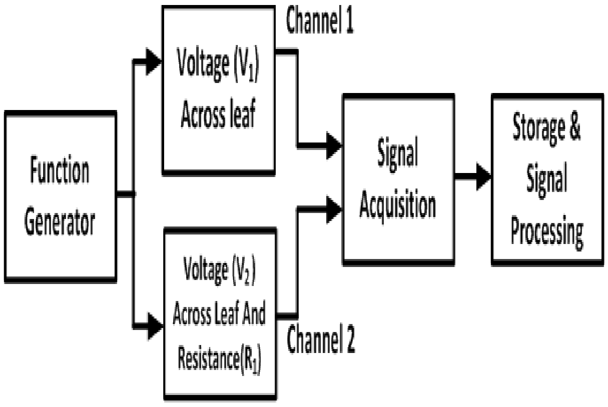

Fig. 5. Block diagram of experimental set up used for estimating the ac impedances of Aloe-vera leaves.

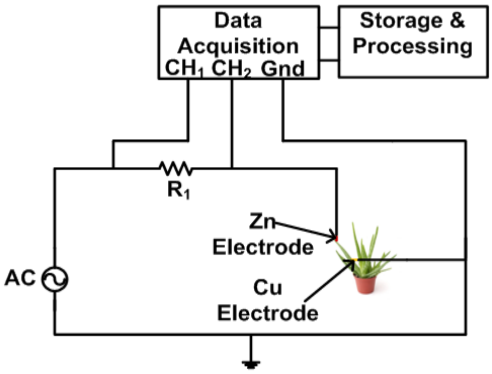

Fig. 6. Equivalent circuit diagram for impedance measurement.

The triangular shaped electrodes of zinc (Zn) and copper (Cu) measuring in area as 0.04 cm^2 with resistance of approximately 0.7 Ω were used for establishing the contact with the leaf tissues. For estimating the impedance the voltages v_1 (across the leaf) and v_2 (applied voltage) with respect to ground were recorded using two channels of a data acquisition card. The impedance of the leaf was estimated by calculating the ratio of rms voltage and rms current derived from the recorded waveforms.

IV. RESULT AND DISCUSSION

An Aloe tissue acts as an ionic conductor. If a direct current is passed through an ionized solution, the well-known phenomenon of polarization occurs, i.e. very rapidly at the level of each electrode a double layer of ions is deposited which acts as an insulator and prevents the current from passing. Therefore, a direct current cannot be used to measure the resistance of such a conductor. Because it is a heterogeneous conductor: i.e. it is composed of both resistive elements and capacitive elements. Whereas the resistive elements allow the alternating current to pass whatever its frequency, the capacitive elements allow the alternating current to pass only if it has a high frequency.

The cellular content of Aloe leaf tissue has three components, the interstitial fluid which is represented by resistance R_{int}, extracellur fluid represented by resistance R_{ext}, which are separated by a cell membrane which plays the role of an insulator or a dielectric which is represented by a capacitor (C). It may be observed that there is an analogy between Aloe leaf tissue and filter network which shows an electric circuit involving the association of a series resistance (R_{ef}) with a capacitive element (C) and another resistance (R_{if}) in parallel. These components are shown in Fig. 7 and Fig. 8.

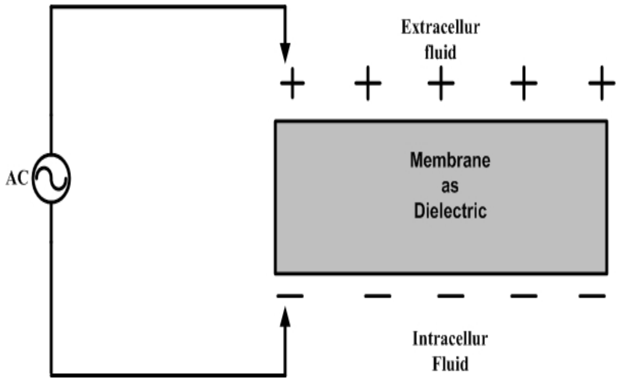

Fig. 7. Equivalent capacitor of Aloe leaf.

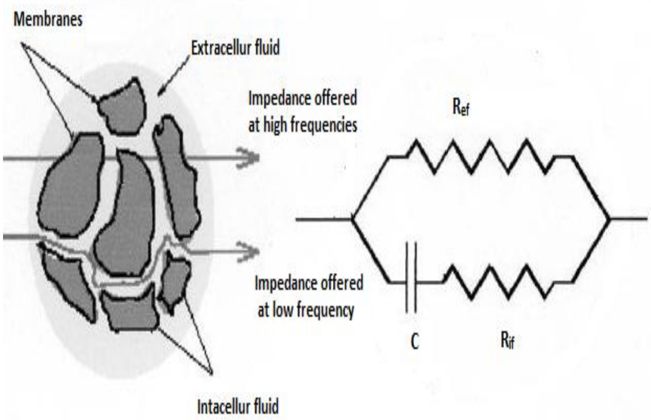

Fig.8. Analogy between an Aloe leaf tissue and a filtering network. This circuit is called an electronic filter as, depending on the value of the capacity C, it does not allow the electric currents to pass except above a given frequency.

Table I represent impedance calculated at different frequencies.

Table. I. Impedance calculated at different frequencies.

Frequency (kHz)	Resistance (KΩ)
0.5	13.07
1.0	12.03
2.0	11.56
3.0	11.39
4.0	11.17
5.0	11.07
6.0	10.91

7.0	10.77
8.0	10.51
9.0	10.45
10	10.39
20	8.660

The impedance curve of this classical circuit is represented in Fig. 9 with respect to the frequency.

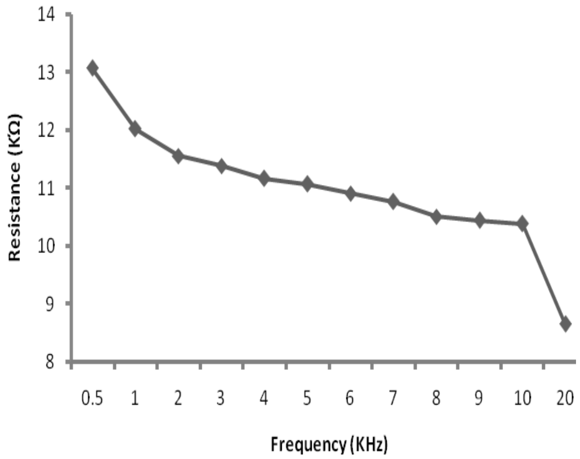

Fig. 9. Variation of Impedance with requency.

The impedance decreases with increase in frequency. At about 1 MHz, there is no more resistance in the Aloe tissue. Low frequencies below 5 kHz only travel through the connective tissue of Aloe leaf. At about 5 kHz, the current begins to penetrate the outside layers of the cell. This scale gradually goes up so that at about 20 kHz the penetration into the cell becomes noticeable. The frequencies from 20 kHz to 1 MHz start penetration into the cell until full penetration is achieved above 1MHz.

The exact relationship of the electrical properties with frequency can be derived by using simple common relations. The electric current in a cellular membrane travels as a displacement current. The density of the electric current *i* is given as

$$i = \frac{dQ}{dt}$$

where Q is the charge (C) and t is the time (s).

The relationship between the density of the current $\vec{J}$ and electric field intensity $\vec{E}$

$$\vec{J} = \sigma\vec{E} = -\sigma\nabla V$$

where σ is the electric conductivity (S/m) and E the intensity of the electric field (V/m).

The Aloe tissues represent three ac current components: conduction current, absorption current, and charging current. Conduction current is independent of time. Absorbance current is due to polarization effect and is given as

$$i_a = At^{-K}$$

The charging current is given by

$$i_c = \frac{V}{R} e^{-\frac{t}{RC}}$$

If the current passing through the material is changing, for density of electric current is valid d(ε E)

$$\vec{J} = \sigma\vec{E} + \frac{d(\varepsilon E)}{dt}$$

where ε is the permittivity of material (F/m).
Complex value of current density is valid in the case of alternating electric field in the shape

$$\vec{J} = (\sigma + j\omega\varepsilon)\vec{E}$$

where E is the electric field intensity and ω the angular frequency. The complex permittivity may be assumed as consisting of real part ε′ and imaginary part ε″

$$\varepsilon = \varepsilon' - j\varepsilon'' = \varepsilon - j\frac{\sigma}{\omega}$$

Thus the dielectric properties are dependent on frequency. As the frequency increases dielectric constant decreases thus the capacitance, which decreases the overall impedance of tissues as shown in Fig 9.

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V. CONCLUSION

The investigations were carried out to study the variation of impedance of the Aloe-vera leaves. The investigations have shown that impedance of the leaves showed a specific non-linear function of frequency. The results may be useful for the assessment of the health status of the Aloe-vera plants for improving the quality of the Aloe products.

REFERENCES

1. Fred and F. Holtzclaw, (2010) " Plant Responses to Internal and External Signal",*AP Biology Reading Guide* Chapter No. 39.
2. E. W. Chehab, Eich, E and , J . Braam (2008), "Thigmomorphogenesis a complex plant response to mechano-stimulation", *Journal of experimental Botany*, Vol. 60, No. 1, pp. 43–56
3. T. Z. Hou, and R. E. Mooneyham, . (1999) "Effect of Agri-Wave Technology on Yield and Quality of Tomato", *An International Journal of Comparative Medicine East and West*, Vol.27, No.01 pp27.
4. P. Weinberger and U. Graefe (1973). "The effect of variable sound-frequency sound on plant growth". *Canadian Journal of Botany*. Vol.51, pp1851-1856.
5. V. D .Yannick, (2000). " Influence of variable sound frequencies on the growth and development of plants" Hogeschool Gent. Belgium. 22 June.
6. P. J. Aphalo, (2006) "Light signals and the growth and development of plants a gentle introduction", *Department of Biological and Environmental Sciences Plant Biology University of Helsinki*, Finland Biology University of Helsinki, Finland.

7. A. Uchida, and K.T Yamamoto,. (2002) "Effects of mechanical vibration on seed germination of Arabidopsis thaliana(L.) Heynh.", *Plant cell physil*. 43(6), pp647-651.
8. S. Lautner, T. E. Edgar Grams, R. Matyssek, and J. Fromm, "Characteristics of Electrical Signals in Poplar and Responses in Photosynthesis," *Plant Physiology*, vol. 138, pp. 2200-2209, 2005.
9. S. Lautner, R. Matyssek & Jorg Fromm, "Distinct roles of electric and hydraulic signals on the reaction of leaf gas exchange upon re-irrigation in Zea mays," *Plant Cell and Environment*., vol. 30, pp. 79-84, 2007.
10. Taiz & Zeiger. 2002. *Plant Physiology*, Third Ed. Sinauer Associates, Inc. Chapter 10, pages 33-46.
11. R Rodr´ıguez, D.Jasso de Rodr´ıguez, J.A.Gil-Margın, Angulo-S´anchez, and Lira-Saldivar, J.L "Growth, stomatal resistance, and transpiration of Aloe vera under different soil water potentials", *sciencedirect*, vol 25 (2007) pp123–128.
12. D. Grindlay, T. Reynolds "The Aloe vera phenomenon: a review of theproperties and modern uses of the leaf parenchyma gel. *J Ethnopharmacol*. (1986) vol 16 pp117-51.
13. I. Danho, "Potential reversal of chronological and photo-aging of the skin by topical application of natural substances. Phytotherapy Research. 1993; 7:S53-S56.
14. A.D Klein, N.S Penneys. Aloe vera. *J Am Acad Dermatol* .1988; vol 18 pp714-720.
15. R. Henry. *An updated review of aloe vera*. Cosmetics and toiletries. 1979; vol 94 pp42-50.

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