Electrical impedance analysis of commonly used preservatives, Nacl (salt) and $C_{12}H_{22}O_{11}$ (Sugar)

Badhe S G and S N Helambe

P.G. and Research center, Dept. of Electronics, Deogiri College, Aurangabad (MS) India
ssnap3@gmail.com

ABSTRACT

In the present work we have studied the properties of the salt and sugar. For this a low frequency TDR is developed in laboratory. One tasted probe is used to collect the information from the sample. Various samples of different molar concentrations (molar conc.0.005-.0.1) of salt with water and sugar with water are prepared. These prepared solutions are kept at different temperatures (25^0C, 35^0C, 45^0C, 55^0C). The electrical parameters like Resistivity, Electrical Conductivity and Dielectric Constant are calculated from TDR waveform. The TDR waveform shows major variations in its nature with change in concentration and temperature. Resistivity of salt increases with increase in concentration while conductivity and Dielectric constant decreases with decease in concentration of salt in water. Whereas Resistivity of sugar solution was decreased with the increase in concentration and no Conductivity was observed in the same solution. There is minor increase in Dielectric Constant. The change in values of electrical parameter with temperature indicates the change in properties of solution with temperature. This helps to decide the food preservation strategy.

KEY WORDS: Dielectric Constant, Electrical Conductivity, Impedance, Resistivity, Spectroscopy.

INTRODUCTION

In our life we use many preservatives like Citric acid, Potassium metabisulphite, Sodium chloride (Salt), Sucrose (Sugar) to preserve food stuffs. Out of these some we purchase from the market and some are easily available in our house like Sodium chloride/NaCl (salt), Sucrose/ $C_{12}H_{22}O_{11}$(sugar). These preservatives stop the microbial action in the food material and keep the food safe.

Impedance spectroscopy (IS) is a general term that subsumes the small-signal measurement of the linear electrical response of a material of interest (including electrode effects) and the subsequent analysis of the response to yield useful information about the physicochemical properties of the system (Macdonald, 1992).

Electrical Impedance Spectroscopy is a leading technique in various industries (We J *et al.,* 2005; Nandkumar V *et al.,* 2008), medical field (Kagan *et al.,* 1977), pathogen detector (Yang *et al.,* 2008), biosensors (Daniel *et al.,* 2007, Srinivasan *et al.,* 2006). In Food industries Impedance spectroscopy is used to detect various Pathogens as well as to check the quality of food material (Pliquett, 2010, Batrinou *et al.,* 2005). It is a fast and effective tool for microbial detection (Ramirez *et al., 2008*; Kern P. *et al.,* 1999). A novel impedance biosensor for bacterial cell detection was constructed (Daniel *et al.,* 2007, Srinivasan *et al.,* 2006) by immobilizing antibodies that are specific to the target bacterial cells on an electrode surface. The impedance spectroscopy used to detect spoilage and quality of bulk food (Bauchot *et al,.* 2000, Cataldo *et al.,* 2009, Weihe JL *et al*., 2006, Bovard FS *et al.,* 1995). The electrical impedance spectroscopy used in diary industry to monitor quality of dairy products (Okigbo LM *et al*., 1985, Walker *et al.,* 2005, Pesta *et al.,* 2007; Pompei *et al.,* 2009).

Salt and sugar are commonly used preservatives and also easily available in house. Salt is used by the ancient mariners to preserve their meat. High levels of sugar can preserve against spoilage organisms, this may be seen in jams, preserves, certain sweet pickles and marmalades. This is also an important factor in the preservation of boiled sweets and chocolates etc. (Batrinou *et al.,* 2005).

MATERIALS AND METHODS

Time domain spectroscopy (TDS) technique studies the Impedance characteristics and gives information in wide frequency range from few MHz to several GHz or even more in just a single measurement. The experimental setup consists of sampling oscilloscope, TDR module, a transmission line, and sample cell. Used TDR setup is a low frequency Time Domain Reflectometry of the range 200MHz and 5ns rise time. A co-axial transmission line with characteristic impedance of 50 ohm was used for study of the preservatives. Various rod type and strip types of probes were designed and studied to check the impedance and conductivity using standard solution of known factors. Out of those a strip type probe of 5.5cm length is used for the further study. For the study of the properties of liquid under consideration we immerse the probe in the liquid and collect the information on the oscilloscope.

Temperature controller unit was developed to control the temperature during the experiment. It consists of water bath with an electric heater and a test tube holder, PT100 to sense the temperature, computer to monitor and control temperature

EXPERIMENTAL PROCEDURE

Commonly used preservatives, Sugar and salt are used to prepare the required solutions. Ten different concentrations (molar concentration 0.005-0.1) are prepared with freshly collected distilled water. These different concentrations are kept in water bath at different temperatures, (250C, 35^0C, 45^0C and 55^0C). The selected probe is attached with pulse generator through coaxial cable and immersed in the solution. A fast rising pulse is applied through the coaxial transmission line. The rising pulse gets reflected back from the solution under consideration. The nature of the pulse is depends on the properties of the liquid. This pulse is observed and stored in the Digital Storage Oscilloscope i.e. DSO. This data was then collected in an external storage and further calculations were done. Each time the probe was thoroughly cleaned with acetone and dried with drier.

RESULTS AND DISCUSSION

The graphs shows the variations of values of Resistivity (R_L), Electrical Conductivity(σ) and Dielectric Constant (ε) for aqueous solution of NaCl (Salt) and $C_{12}H_{22}O_{11}$ Sucrose (Sugar) of various concentrations at four different temperatures 25^0C, 35^0C, 45^0C and 55^0C.

In Fig. 1, the resistivity of aqueous solution of NaCl decreases with increase in temperature. The decrease in the resistivity value is exponential with increase in concentration of NaCl in the solution.

The aqueous solution of sugar shows distinct nature of resistivity with increase in concentration and temperature. Very slight change is observed in resistivity of solution when temperature is increased (Fig. 2).

The commonly used preservative NaCl shows non-linear increase in electrical conductivity, with increase in concentration of NaCl in solution of distilled water (Fig. 3).Increase in electrical conductivity was observed at all four temperatures. There are no remarkable changes are observed in the graphical behavior of conductivity of sugar. The aqueous solution of NaCl shows increase in dielectric constant with increase in concentration. The effect of temperature is more at higher concentration. The dielectric constant increases with increase in temperature (Fig. 4).

The aqueous solution of sugar shows very small variation in dielectric constant with concentration and temperature as shown in Fig. 5.

CONCLUSION:

The Resistivity of aqueous solution of NaCl decreases about 67%. The 60% decrease in resistivity is observed at 55^0C. The decrease in the resistivity value is exponential with increase in concentration of NaCl in the solution. The preservative NaCl shows non-linear increase in Electrical Conductivity with increase in concentration of NaCl in solution of distilled water. This increase in Electrical Conductivity is observed at all four temperatures. The Dielectric Constant increases with increase in temperature.

There is very less decrease of 6% in Resistivity of solution when molar concentration of sugar in solution is increased from 0.005 to 0.1. Very slight change is observed in Resistivity of solution when temperature is increased from 25^0C to 55^0C. No Electrical Conductivity observed in sugar. The aqueous solution of sugar shows very small variation in Dielectric Constant.

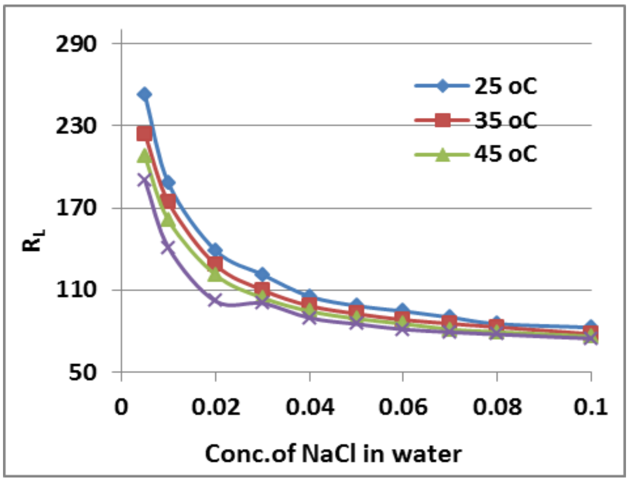

Fig.1 Variation of R_L with conc. of NaCl in water

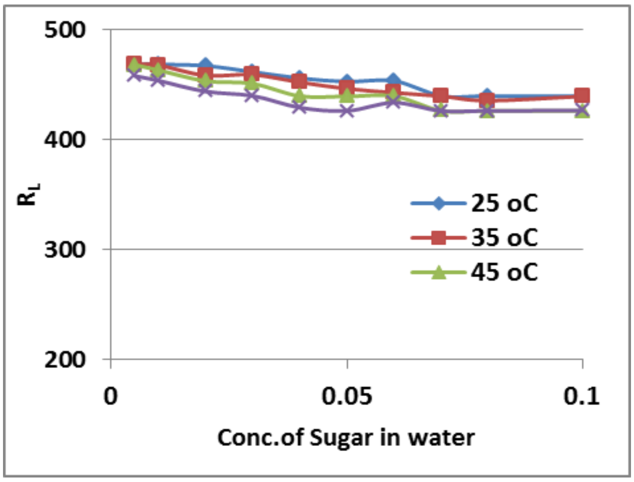

Fig.2 Variation of R_L with conc. of $C_{12}H_{22}O_{11}$ Sucrose (Sugar) in water

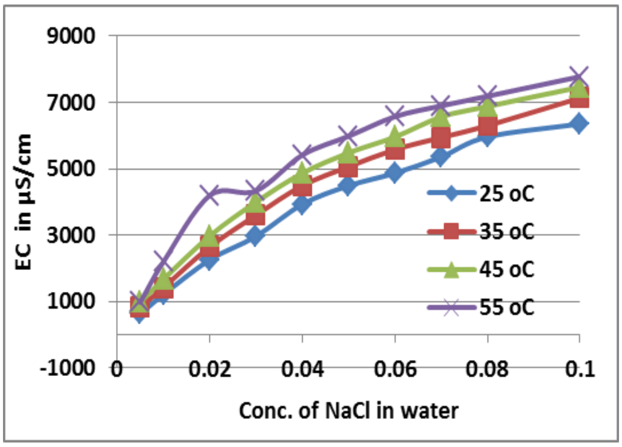

Fig. 3 Variation of Electrical Conductivity of NaCl in Water

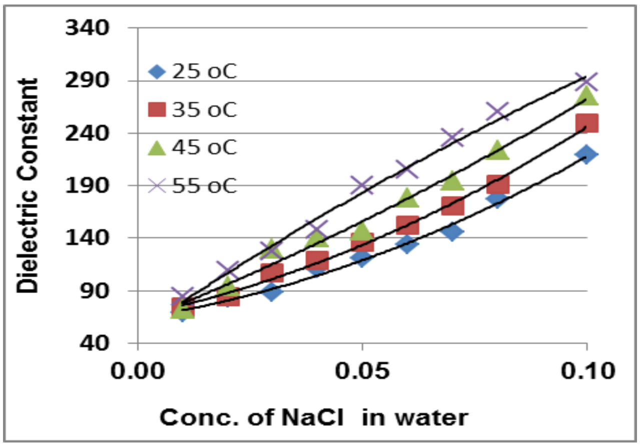

Fig. 4 Variation of dielectric constant of NaCl in water

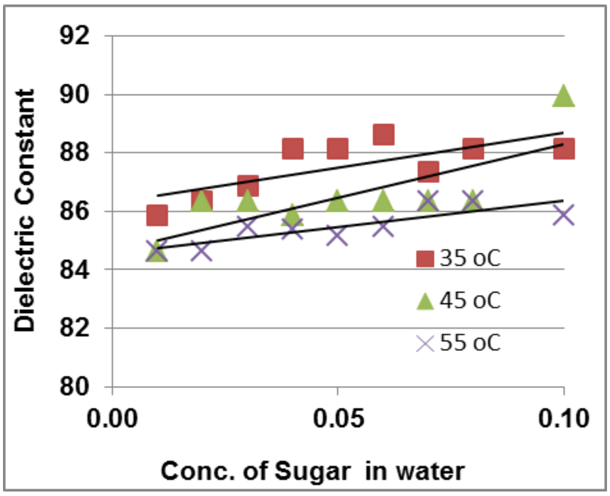

Fig. 5 Variation of dielectric constant of $C_{12}H_{22}O_{11}$Sucrose (Sugar) in water

LITERATURE CITED

Batrinou AM, Katsogiannos ED, Koustoumpardis EN and Spiliotis VK, 2005. Estimation of microbial population of bitter chocolate mix by impedance measurement. *Nutrition*. **29**:260 -264.

Bauchot AD, Harker FR and Arnold WM, 2000. The use of electrical impedance spectroscopy to access the physiological conditions of kiwifruit. *Postharvest Bio. and Tech*. **18** (1): 9-18.

Bovard FS, Burleigh TD and Smith AT, 1995. Electrochemical Impedance spectroscopy of electrocoated aluminium food cans. *Electrochemical acta*. **40** (2): 201-207(7).

Catald A, Piuzzi E, Cannazza G, De Benedetto E and tarricone L, 2009. On the use of dielectric spectroscopy for quality control of vegetable oils. *XIX IMKEO world congress*. *fundamental and applied Metrology*: 433-437.

Danie lJS and Pourmand N, 2007. Label-free Impedance Biosensor: opportunities and challenges. *Electroanalysis*. **19** (12):1239-1257.

Filho PB, Valicheski R, Pereira RM and Paterno AS, 2010. Bioelectrical impedance analysis for bovine milk: Preliminary results, *J. of Physics*: Conference Series **224.**

Grossi M, Pompei A, Lanzoni M, Lazzarini R, Matteuzzi D and Ricco B, 2009. Total Bacterial Count in Soft-Frozen Dairy Products by Impedance Biosensor System. *IEEE Sensors J. **9***:1270-1276.

Kagan RL, Schuette WH and Zierdt CH, 1977. Rapid automated diagnosis of bacteremia by impedance detection. *J. of clinical microbiology*. **5**(1): 51-57.

Kern P, Baner AL and Lange J, 1999. Electrochemical Impedance spectroscopy as a tool for investigating the quality and performance of coated food cans. *J. of coatings tech.* **71**: 67 -74.

Macdonald JR, 1992. Impedance spectroscopy. *Analysis of Biomedical Engineering*. **20**:289-305.

Nandkumar V, Jeffrey T. Belle L, Reed J and Shah M, 2008. A methodology for rapid detection of Salmonella typhimurium using label free electrochemical impedance spectroscopy. *Biosensors and Bioelectronics*, **24**:1039-1042.

Nelson SO, Trabels iS and Zhuang H, 2007. Dielectric spectroscopy of fresh chicken breast meat. *American society of agricultural and biological engineering*, paper no. 073095.

Okigbo LM, Oberg CJ and Richardson GH, 1985. Lactic culture activity tests using ph and impedance instrumentation. *J. dairy Sci*. **68**: 2521–2526.

Pesta M, Williams P, Zampa N, 2007. The effect of raw milk storage conditions on freezing point. Ph and impedance. *Advanced Instruments,* INC., pp: 1-7. http://www.aicompanies.com

Pliquett U, 2010. Bioimpedance: A Review for Food Processing. *Food Eng Rev.* **2**: 74–94.

Ramirez N, Regueiro A, Arias O and Contreras R, 2008. Electrochemical Impedance Spectroscopy: An effective tool for a fast microbial diagnosis. *Biotechnolgia Aplicada*. **26** (1): 72 -78.

Srinivasan B, Tung S, Li Y and Varshney M, 2006. Simulation of electrical impedance based microfluidic biosensor for detection of E.coli cells. COMSOL Users con. Boston.

Walker K, Ripandelli Nand Flint S, 2005. Rapid enumeration of Bifidobacterium lactis in milk powders using impedance. *Inter. dairy J.* **15**: 183 -188.

We J, Ben Y and Chang H-C, 2005. Particle detection by electrical Impedance spectroscopy with asymmetric polarization AC electroosmotic trapping. *Microfluid Nanofluid*, **1**:161-167.

Weihe JL, Seibt SL and Hatcher WS, 2006. Estimation of Microbial Populations in Frozen Concentrated Orange Juice using Automated Impedance Measurements. *J. of food sci*., **49**(1): 1365-2621.

Yang L and Bashir R, 2008. Electrical/Electrochemical impedance for rapid detection of foodborne pathogenic bacteria. *Biotech. Adv.*,**26**:135-150.

How to Cite this Article:

Badhe SG and SN Helambe, 2013. Electrical impedance analysis of commonly used preservatives, Nacl (salt) and C12H22O11 (Sugar). *Sci. Res. Rept.,* **3**(2):239-242.