Proceedings of the
International Conference on Mechanical Engineering and Renewable Energy 2017
(ICMERE2017) 18 – 20 December, 2017, Chittagong, Bangladesh

ICMERE2017-PI-000

CONDUCTIVITY BASED CONCENTRATION MEASUREMENT TECHNIQUE FOR DETECTING ADULTERATION

A. B. Patwary, Sabrina Abedin, Tasfia Tasbin and Nursadul Mamun*

Dept. of Electronics and Telecommunication Engineering,
Chittagong University of Engineering and Technology, Bangladesh
adnanbasir27@gmail.com, sabrinaabedinete@gmail.com, isha.tasfia@gmail.com, nursad49@gmail.com

Abstract- *Necessity of concentration measurement is mandatory in various aspects. In numerous industries and factories the exact liquid concentration is required to make perfect product. Sometimes, they add various unhygienic products as solutes with the main element to increase profit margin. However, available concentration measurement kits are not cost effective. This study proposes a concentration detection kit using electrical conductivity property of the solutes. The kit determines the presence of solute and their percentage in the solution. Here, conductivity was measured in different concentrations and output was measured accordingly. The proposed kit could be effectively used to avoid food adulteration.*

Keywords: Conductivity, Adulteration, Concentration, Formalin.

1. INTRODUCTION

The term 'food adulteration' can be simply defined- as an act of intentional debasing the quality of food offered for sale either by the admixture or substitution of inferior substances or by the removal of some valuable ingredient [1]. On the other hand the word **'**adulterate**'** implies an element of deceit. According to the definition of Chamber's Dictionary it means '*to debase, falsify by mixing with something inferior or spurious*' [2]. The major reason of this intentional addition of adulterants is to increase the profit margin. The food safety situation in Bangladesh is at an alarming stage due to food adulteration, use of toxins, pesticide residues, microbiological contamination, veterinary drug residues and heavy metals. It is paradoxical to say that the safety of food cannot be ensured due to the dilemma of existing legal paradigm in Bangladesh. At present, it has become acute problem in Bangladesh. There are hardly any food items from fish to meat, fruit to milk that are free from adulteration [3]. Several initiatives have been taken to detect impurities in liquid. Recently, a new method has invented to detect formalin in fish [4]. Several methods of detecting different types of food adulteration are discussed in [5-6]. In food industry, there is a need of tasting the food products. Such a method to determine the sugar content in sugar solutions is proposed [7]. In another study different types of food adulteration like intentional, unintentional, metallic, microbial etc. and health risk of these types of adulteration along with their detecting methods are presented [8]. Another research was performed on common food adulterants and knowledge about adulteration where observation results describe about the awareness of people [9]. In this study, a method for the measurement of concentration of solutes in any solution is proposed. The proposed method is based on the property of electrical conductivity of solutes. Conductivity is a measure of how well a solution conducts electricity. When the concentration of solutes increases, probe resistance (R_p) changes as conductivity increases and also the output voltage also changes accordingly.

Concentration is a measure of how much solute is dissolved within the solvent. Concentration may be expressed in a number of ways. The simple statement of the concentrations of the components of a mixture is in terms of their percentages by weight or volume. There are three different types of percentage concentrations commonly used. The mass percent is used to express the concentration of a solution when the mass of a solute and the mass of a solution is given. The second one, volume percent, is used to express the concentration of a solution when the volume of a solute and the volume of a solution is given. Another version of a percentage concentration is mass/volume percent, which measures the mass or weight of solute in grams (e.g., in grams) vs. the volume of solution (e.g., in mL) as shown in equation 1.

$$\text{Mass /volume Percent} = \frac{\text{Mass of Solute (g)}}{\text{Volume of Solution (mL)}} \times 100\% \quad (1)$$

2. METHODOLOGY

Three substances (salt, sugar, milk) as solutes and water as solvent were used to make the solutions in this study. The conductivity of each solution was then measured for different concentrations. Pure water contains very few ions; therefore it does not conduct electricity very well. As more and more salt is dissolved in water, the free ions of the solution increase and the conductive property of the solution increase subsequently. Salt (Sodium chloride) contains sodium ions, which have a positive charge, and chloride ions, which have a negative charge. The number of ions available in the solution depends on the property of the substance. Few substance like salt release ions where others (such as sugar) release uncharged particles called molecules. When sugar is dissolved in water, the solution does not conduct electricity, because there are no ions in the solution. Therefore, voltage across the ports for sugar will be much lower than the pure water. On the other hand, milk is not a pure substance; it is considered a mixture because it does not occur naturally on its own. Milk is a homogeneous rather than heterogeneous mixture. The reason for this is that the different chemical components (water, fat, proteins, lactose; which is called milk sugar and minerals, for example salts) that comprise milk are not visibly separate. The changes in electrical conductivity of milk, primarily because of changes in the concentration of sodium, potassium and chloride ions [10]. The above properties of the solutes are used to design the proposed concentration measurement system.

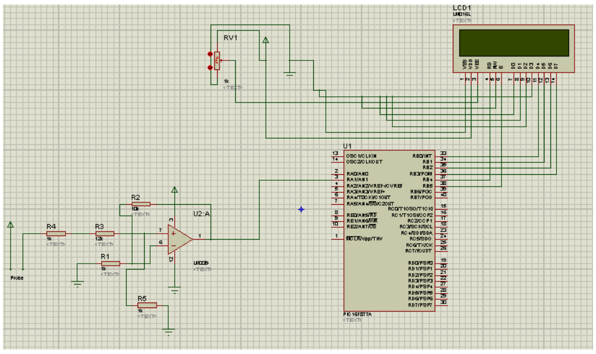

Fig.1: Circuit diagram of the proposed concentration detector.

2.1 Circuit Diagram

The circuit displayed in Fig. 1 consists of a non-inverting amplifier circuit, a microcontroller circuit and an LED display. Non-Inverting amplifier (IC LM 339) is connected to the probe which is used to measure the resistance of the solution. As probe resistance varies from solution to solution and also varies for different concentration of a solution, different output voltage is obtained accordingly across the probe. The arrangement of non-inverting amplifier is demonstrated in Fig. 2. The distance between the probes is maintained 0.55 cm and the probe resistance is considered to be approximately zero.

The microcontroller circuit (16F877A for this study) is the heart which consists of the algorithm that determines the concentration. The input voltage was taken through the ADC pin of microcontroller which takes the analog input. An equation is formed from the recorded data for some fixed concentrations of each solution which is used for the logical operation of microcontroller to give concentration as output taking voltage as input. This equation varies from solution to solution. The output from the microcontroller is displayed on the LCD display. From the equation derived for each solution, the microcontroller gives out the concentration to the decimal points.

For all three solutions of milk, sugar and salt, output voltages for four levels of concentration such as 100%, 50%, 25%, and 12.5% were recorded and an equation has been derived for each solution. Using this equation, percentages of concentration have been shown in output device.

The relation between Output voltage, V_{out} and probe resistance, R_p is shown in equation 2.

$$V_{out(a)} = 0$$

$$V_{out(b)} = V_{in}\left(\frac{R_1}{R_1 + R_2 + R_p}\right)\left(1 + \frac{R_f}{R_i}\right) \quad (2)$$

Where (V_{in} = 4.9V) is the input voltage which is applied to the circuit.

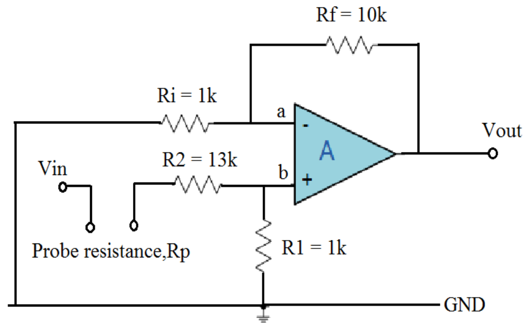

Fig.2: Experimental setup for closed loop non-inverting amplifier.

The final output was found using the following equation,

$$\begin{aligned} V_{out} &= V_{out(b)} - V_{out(a)} \\ &= V_{in}\left(\frac{R_1}{R_1 + R_2 + R_p}\right)\left(1 + \frac{R_f}{R_i}\right) - 0 \\ &= 4.9 \times \left(\frac{0.99}{0.99 + 12.74 + R_p}\right) \times \left(1 + \frac{9.74}{0.99}\right) \\ &= \frac{52.773}{13.73 + R_p} \end{aligned} \quad (3)$$

3. RESULTS AND DISCUSSION

The data collected from the probe can be observed in Table 1. The data clearly shows that output voltage, V_{out} varies with the change of concentration of the solution. There is a gradual change in the output voltage for the salt solution with 132 mV, 130 mV, 125 mV, 123 mV, 91 mV for the 100%, 50%, 25% and 12.5% concentrated solution, respectively.

Table 1: Experimental data

Type of liquid	Vout for 100% Solution in mV	Vout For 50% Solution with water in mV	Vout For 25% Solution with water in mV	Vout For 12.5% Solution with water in mV	Vout For the pure water in mV
Sugar	81	79	76	75	91
Salt	132	130	125	123	91
Milk	110	101	98	93	91

Figure 3 shows the graphical representation of the output voltage as a function of concentration of the proposed system which can be represented with the following non-linear equation.

$$y = 3E - 55\, x^{26.669} \qquad (4)$$

Where, E=10 and x is the V_{out} that is obtained from the probe and y represents the value of the concentration of the liquid.

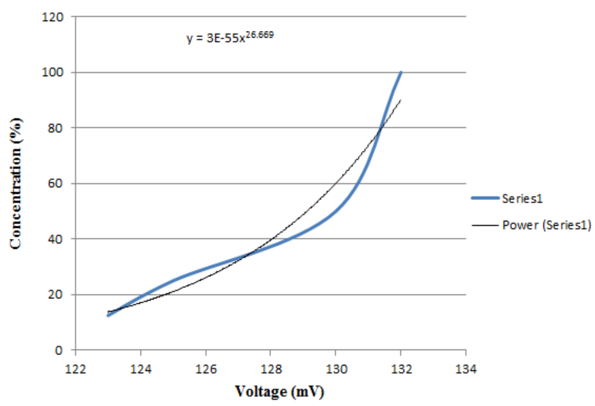

Fig.3: Graphical representation of concentration as a function of output voltage for salt

The percentage of adulteration can be observed for the salt solution easily using equation 4 by measuring the output across the solution.

Figure 4 represents the relationship between concentration of liquid (milk) and the desired output voltage for the liquid across probe. For a given liquid with unknown concentration can be determined by using equation 4 where voltage across the liquid can be measured using the proposed circuit as shown in Fig.2, thus determine the percentage of adulteration.

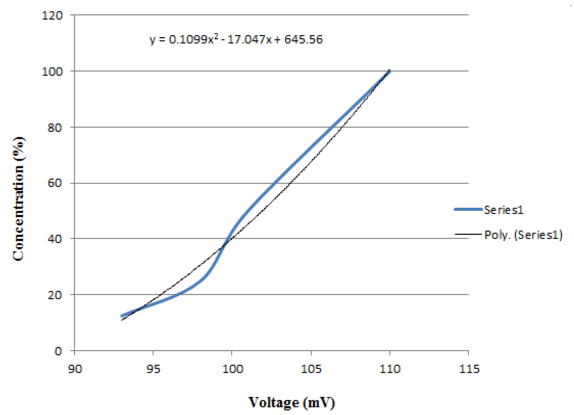

Fig.4: Graphical representation of concentration as a function of output voltage for milk

The relationship between concentration of milk and output voltage across the circuit can be represented as,

$$y = 0.0199\, x^2 - 17.047x + 645.56 \qquad (5)$$

Where x represents the output voltage (V_{out}) across the probe for the given liquid and y is the concentration of the liquid.

The similar experiment was done for sugar solution. The output voltages were found as 81, 79, 76, 75 and 91 mV for the concentration of 100%, 50%, 25%, and 12.5% respectively as shown in Fig.5.

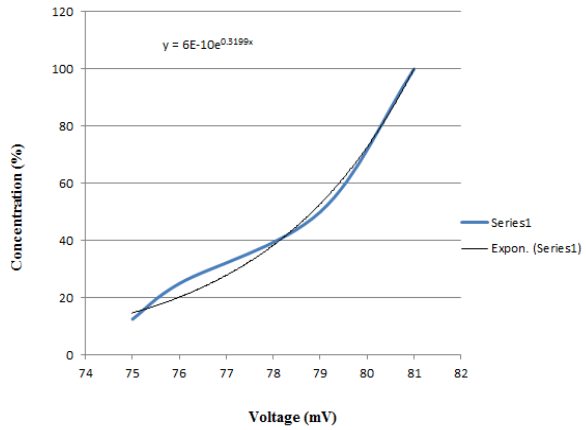

Fig.5: Graphical representation of concentration as a function of output voltage for sugar.

An equation can be developed from the relationship between the concentration of the sugar and the output voltage from the probe and the equation is,

$$y = 6E - 10\, e^{0.3199x} \qquad (6)$$

Equation 6 is the derived equation for the sugar solution where E=10, x is the output voltage from the probe and y is the concentration of sugar.

The value of the R_p can be derived using equation 3. The values of R_p for different concentration of the salt, milk and sugar solutions are given in Table 2.

Table 2: Data for the resistance for all the solutions

Salt	Concentration (%)	0	12.5	25	50	100
	V_{out} (mV)	91	123	125	130	132
	R_p (KΩ)	0.56	0.41	0.408	0.39	0.38
Milk	Concentration (%)	0	12.5	25	50	100
	V_{out} (mV)	91	93	98	101	110
	R_p (KΩ)	0.56	0.553	0.524	0.508	0.466
Sugar	Concentration (%)	0	12.5	25	50	100
	V_{out} (mV)	91	75	76	79	81
	R_p (KΩ)	0.56	0.689	0.680	0.654	0.637

The result obtained from the circuit will be observed on the LCD display. The probe takes the voltage from the solution and the non-inverting amplifier amplifies it. Then it sends the analog voltage data to the microcontroller which turns it into digital data and the program in the microcontroller calculates the input and shows the output in the LCD display.

4. CONCLUSION

This study demonstrates the technique to determine the concentrations of different product dissolved in water. The system measures the voltage across the probe for the given liquid and determines the corresponding concentration using the equation thus determining the percentage of adulteration in the liquid. The system is cost effective, easy to use and gives reliable result. The proposed system is able to measure the concentration of homogeneous and as well as heterogeneous solvents. It is necessary to clean the probes after each experiment with pure water. The proposed system could help the present scenario of food adulteration in Bangladesh.

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