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Detection of Adulteration in milk using capacitor sensor with especially focusing on Electrical properties of the milk. †

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Abstract: With the growth of population, the demand of milk is increasing at very fast rate. Due to this increasing demand, adulteration of milk by various substances has been very common in throughout the world, which not only reduces the nutritional value but also causes various diseases to human being. The common adulterants used in adulteration are detergents, ammonium sulphate [$(NH_4)SO_4$], sodium hydroxide ($NaOH$), sodium-bi-carbonate ($NaHCO_3$) and salt ($NaCl$), fat. The aim of this paper is to trace / detect the above six adulterants in the milk. A capacitor sensor is used, which is sensitive to an electrical property of the measuring medium and gives different dielectric loss angle of the milk sample under measurement, when sensor is immersed in different adulterated/unadulterated milk. The tangent of dielectric loss angle (tan Delta) is measured by Schering Bridge. By this sensor measurement system, adulterants detection in milk with different % (from 5% to 20%) is studied. Packet milk and raw-milk (collected from the dairy farm) are utilized in the experiment. Experimental results of various adulteration levels are plotted for results verification and for checking consistency of data.

Keywords: Adulteration ; Capacitor sensor; tan delta ; Schering Bridge ; Raw Milk

1. Introduction

Milk is a vital nutrient source which is required for infant's growth and children and a major supplement for the health of adults. Milk is a complete diet, which is easily absorbed and digestible. It is a god gifted natural food for infants and children.

But these days it is being adulterated with harmful substances which enhance its quantity and characteristics but reduces its quality [11]. Adulterants are basically added to increase the life of milk. Adulteration in milk is considered to reduce the quality and to increase the quantity of milk. Normally, the adulteration is done with a purpose of financial gain or improper and unhygienic processing conditions, storage, transportation and marketing. This solely affects the consumer which is either cheated or becomes a prey for diseases. It is of worth that the consumer must know the common adulterants and their adverse effects on health. Since Milk is a perishable liquid which is most likely to be spoiled during transportation in summer.in order to preserve it for long time The middlemen mixes some chemical preservatives such as penicillin, strepto penicillin, formaldehyde, hydrogen peroxide, sodium bicarbonate [12]. The consumer consumes adulterated milk which is diluted to such an extent that it is having less nutritive value , leading concern and malnutrition of public health.

1.1 Identification of substances used in Adulteration

An adulterant is a substance which is not allowed for legal or several other reasons. The addition of adulterants is called adulteration. The adulterants/preservatives assume the proportion of health risks for consumers, particularly infants milk Suppliers have found ways to boost their profit margin by selling milk:

(i) Infusion

(ii) Separation of key ingredients, i.e. milk cream,

(iii) Above methods with the addition of cheap and harmful add ones, like low quality flour.

2. Adulterant Materials

Table. 1 Injurious Adulterants/Contaminants used in milk and their Health Effects

S. No	Adulterants	Diseases or Health Effects
1	Water dilution	This not only reduces its nutritional value, but contaminated water can also cause additional health problems.
2	Urea	Vomiting, nausea and gastritis
3	Starch	Solid milk paste can cause stomach diseases [6]
4	Detergent	The detergent has sodium, acting as slow poison for hypertension and heart ailments patients.
5	Caustic Soda	Dangerous for people suffering from hypertension and heart ailments. Affects the food pipe mucosa, especially in kids
6	Formalin	Causes more severe damage to the body like liver damage
7	Oil	Gives creamy texture to the milk and is very bad for consumption
8	Other synthetic compounds	The other synthetic compounds impair the functioning of various organs of the body, cause heart problems, cancer, and sometimes death.

3. Methods

The methods used for measuring 'loss tangent', tan delta and capacitance with high precision is the high-voltage Schering bridge, originally patented by P. Thomas in 1915 and introduced to h.v. measurements by H. Schering in 1920.(15, p.212). A schering bridge network indicates the dielectric loss angle δ of a sample liquid. In sensitive measurements Tan δ is basically measured by Schering Bridge used for high voltage. But this system is not equally good for continuous measurement process. The Tan δ of milk is required to be known accurately by application circuits like Schering Bridge. This bridge can measure both dielectric loss angle and relative permittivity constant with accuracy. For use in this application Schering Bridge is incorporated with Wagner earth device for accurate bridge networks measurement of δ (loss angle) and relative permittivity constants of milk.

Because of presence of stray capacitance between output points and the accuracy in the measurement of objective parameters will be inaccurate. In Schering Bridge the measurement errors are avoided by the use of Wagner earthing mechanism. By mechanism balancing of bridge are made at Wagner earth and bridge position. Thus the output nodal points of a bridge is almost held at the same ground potential. By this measurement error because of stray capacitance is reduced.

$$\text{Tan}\ \delta = \varepsilon''/\varepsilon' \qquad (1)$$

Where ε′ is minimum relative permittivity and ε″ is peak dielectric loss. The parameter Tan δ is called loss tangent or dissipation factor [7], which is an indication of life expectancy of an insulation or dielectric medium. The lower the value of Tan δ better is the life of insulation i.e. the insulation can withstand/hold electromagnetic energy by itself and there is no loss in that energy.

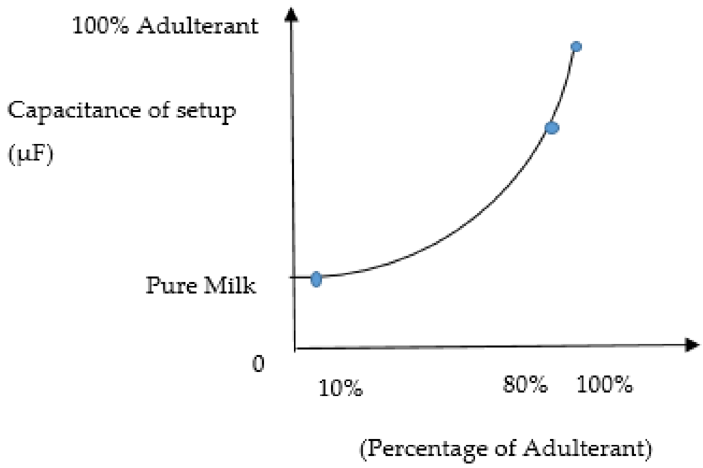


Figure 1. The curve shows the behaviour of capacitor cell setup by a nonlinear response as percentage of adulterant changes.

The unprocessed milk had the minimum relative permittivity (ε′) if frequency is greater than 20MHz, gives peak dielectric loss (ε″) or depreciation factor tan δ. The loss index may be a pointer in forecasting concentration of milk and originality [3]. The permittivities are also temperature dependent that's why in this research the temperature is assumed to be constant [4].

Dielectric properties [5] include dielectric constant and dissipation factor, in which the dielectric constant is usually used to describe the dielectric characterization of a material. The lower the dielectric constant (κ) and dissipation factor, the lower energy is absorbed in an electric field. Since conventional approach for assessing milk quality are drawn out, labor-demanding, and pricey. The advanced technique of capacitor cell method associated with dissipation factor meter is useful technique to assess dielectric properties [13].

The objectives of this research is to study the influence of added adulterant content on milk concentration and freshness with the capacitor technology.

3.1. Mixture Sample (Homogeneous)

The capacitor cell should be feed with a standard fluid in order to have an accurate result of measured value. The major problem found in adulteration measuring in oil is because of the presence of air bubbles or foams formed during pouring of oil in the fuel cell. At that moment the capacitive fuel cell is exposed to multiple parallel and very indifferent phases. Fluid Adulteration testing circuitries are based on the single-phase measurement and now must attempt to understand a multiphase system having a free air and emulsions of milk.

A multiphase process comprising of milk, adulterants and air bubble is to be avoided. Therefore, the adulteration device assumes a single phase measurement. Also all the experiments are performed at room temperature i.e 25^{0}C [2] and small changes in ambient temperature does not have appreciable effect on experimental values [1].

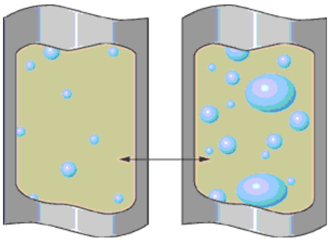


Figure 2. Adulteration devices assume a single phase measurement. A multiphase process comprising a milk , water and air bubble emulsion should be avoided.

3.2. Sample

The fresh untreated raw cow milk (raw milk) was obtained from a local farm house at some time before performing experiment in the morning, and was filled in two plastic bottles of 1000 ml sterilized with boiling water [7][8].

3.3. Dielectric properties measurement

The dielectric properties were measured with the help of capacitor cell and tan delta bridge setup [9].

3.4. Procedure

Predetermined amounts of adulterants were added to 1000 ml of raw milk to prepare milk solutions with different milk for quality control of milk based on dielectric properties measurements.

3.5. Theorotical Experimental setup [10]

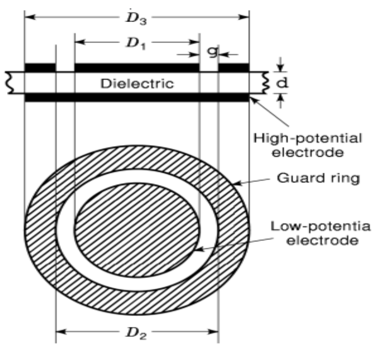


Figure 3. The Bottom part of experimental setup comprising of guard ring.

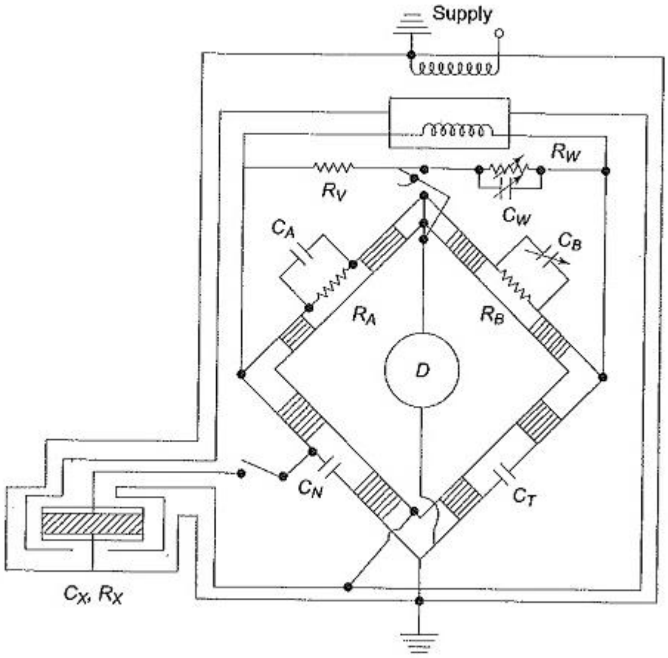


Figure 4. Schering Bridge using Wagner Earthing device with experimental setup.

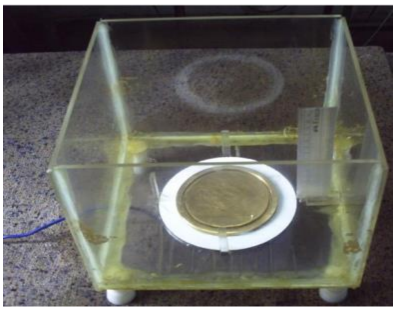


Figure 5. Capacitor Cell Bottom Part

Figure 6. Capacitor Cell Top Part

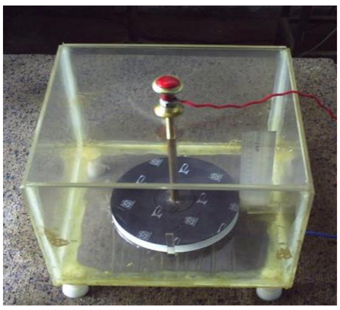


Figure 7. Capacitor Cell

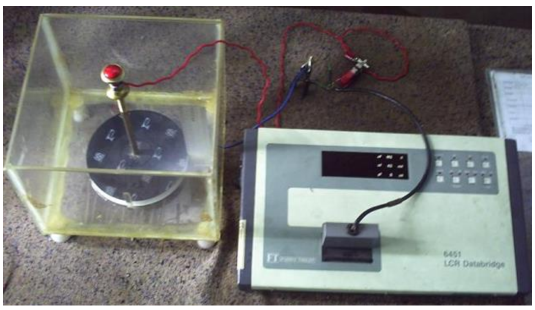


Figure 8. Complete Experimental setup

Table 1. Using water as an adulterant in Milk sample of 1000 ml. [14]

Sample	Volume Ratio (Milk:Water) ml	Water Addition (%)	Capacitance of Fuel Cell (pf)	Relative Permitivity (ε_r)	Dissipation Factor (Tanδ)	Loss Index (ε_r tanδ)
1	1000:00	0	156.763	75.8	7.373	558.880
2	950:50	5	155.157	75.1	7.656	574.966
3	900:100	10	157.636	76.3	7.998	610.247
4	850:150	15	157.636	76.3	8.212	626.576
5	800:200	20	157.842	76.4	8.885	678.814
6	750:250	25	157.636	76.3	9.155	698.527
7	700:300	30	157.842	76.4	9.458	722.591

[1] Sample volume of milk is 1 Litre.

Table 2. Using urea as an adulterant in Milk sample of 1000 ml

Sample	Volume Ratio (Milk:Urea) ml	Urea Addition (%)	Capacitance of Fuel Cell (pf)	Relative Permitivity (ε_r)	Dissipation Factor (Tanδ)	Loss Index (ε_r tanδ)
1	1000:00	0	140.695	68.1	6.554	446.327
2	950:50	5	139.868	67.7	6.356	430.301
3	900:100	10	142.554	69.0	6.124	422.556
4	850:150	15	143.587	69.5	5.889	409.286
5	800:200	20	144.413	69.9	5.763	402.834
6	750:250	25	145.446	70.4	5.445	383.328
7	700:300	30	146.479	70.9	5.225	370.453

Table 3. Using starch as an adulterant in Milk sample of 1000 ml

Sample	Volume Ratio (Milk:Starch) ml	Starch Addition (%)	Capacitance of Fuel Cell (pf)	Relative Permitivity (ε_r)	Dissipation Factor (Tanδ)	Loss Index (ε_r tanδ)
1	1000:00	0	136.149	65.9	6.333	417.345
2	950:50	5	135.529	65.6	5.974	391.894
3	900:100	10	138.215	66.9	5.556	371.696
4	850:150	15	139.455	67.5	5.321	359.168
5	800:200	20	140.488	68.0	4.832	328.576
6	750:250	25	141.521	68.5	4.654	318.799
7	700:300	30	142.761	69.1	4.525	312.677

Table 4. Using detergent as an adulterant in Milk sample of 1000 ml

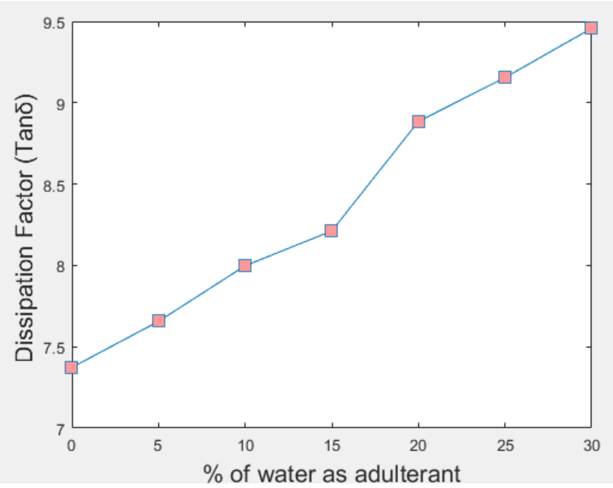
Sample	Volume Ratio (Milk:Detergent) ml	Detergent Addition (%)	Capacitance of Fuel Cell (pf)	Relative Permitivity (ε_r)	Dissipation Factor (Tanδ)	Loss Index (ε_r tanδ)
1	1000:00	0	128.918	62.4	5.554	346.567
2	950:50	5	128.505	62.2	5.450	338.99
3	900:100	10	131.811	63.8	5.225	333.355
4	850:150	15	132.844	64.3	5.132	329.988
5	800:200	20	133.670	64.7	5.242	339.157

6	750:250	25	134.497	65.1	5.265	342.752
7	700:300	30	135.736	65.7	4.845	318.316

3.3. Sample Cpacitance Calculations

From Table 1. For pure raw milk:
Volume Ratio: 1000:00 ml
ε_r (Relative Permittivity) = 75.8
Dissipation Factor (Tanδ) = 7.371
D= diameter of capacitor plate
d= Distance between capacitor plates =0.03m
A= overlapping area of capacitor plates = $(\pi/4)D^2$ =0.007m^2
C=εA/d =8.854*10^{-12} *75.88*0.007/0.03 = 156.763pF

4. Results and Discussions



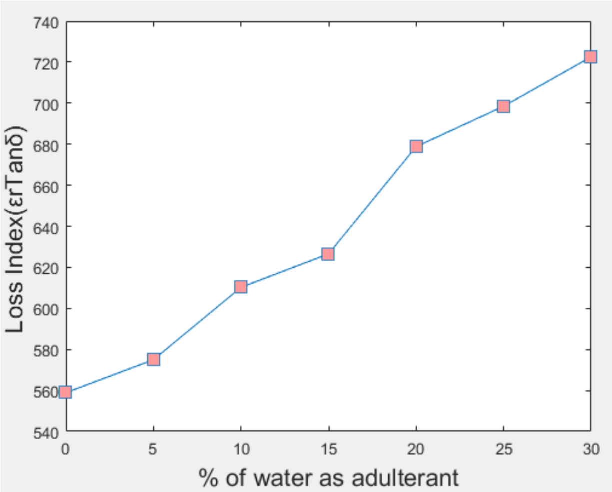
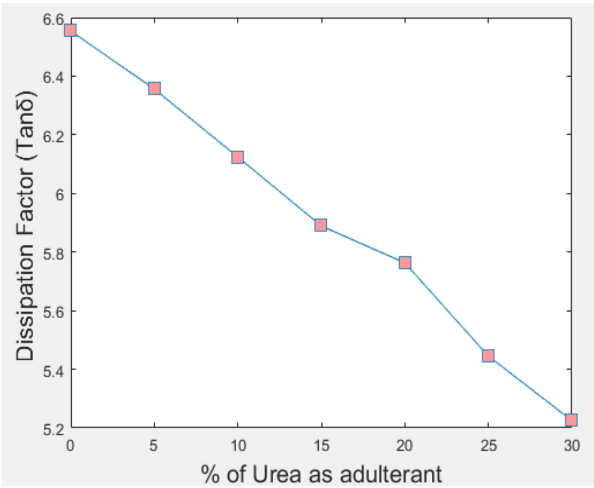


Figure 8. Plot of tan δ and % of water adulterant **Figure 9.** Plot between ε_r tan δ and % of water adulterant



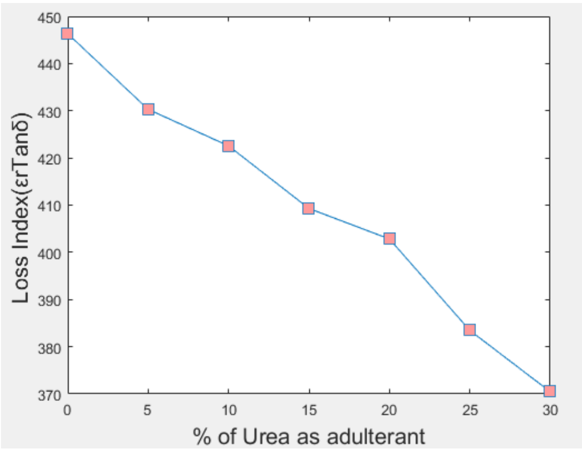


Figure 10. Plot between tan δ and % of urea adulterant

Figure 11. Plot between ε_r tan δ and % of urea Adulterant

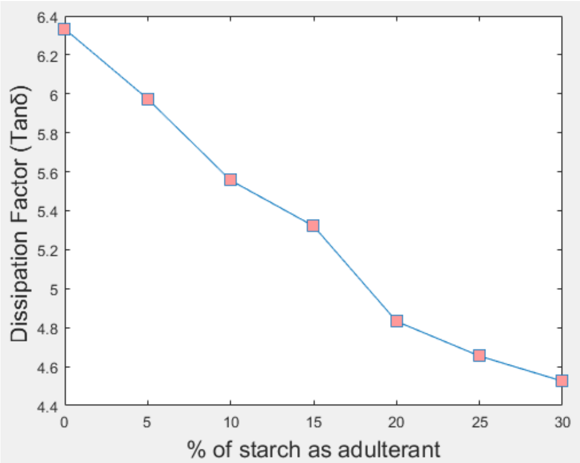


Figure 12. Plot between tan δ and % of starch adulterant

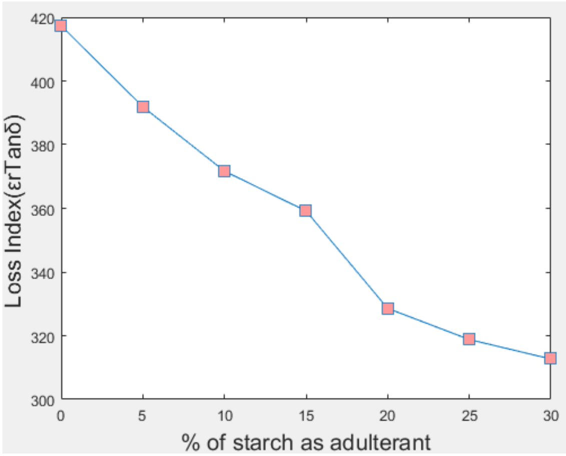


Figure 13. Plot between ε_r tan δ and % of starch adulterant

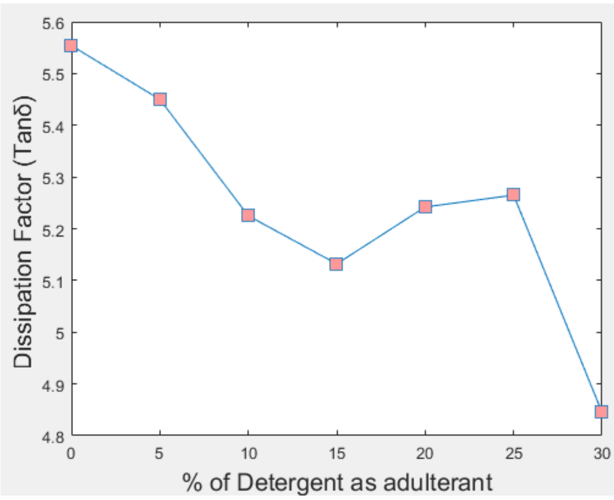


Figure 14. Plot between tan δ and % of Detergent adulterant

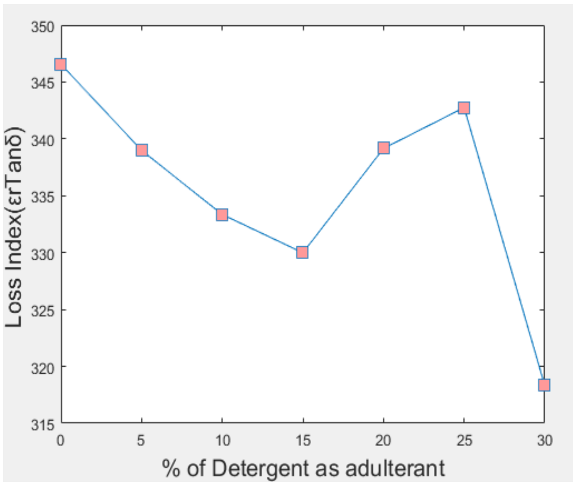


Figure 15. Plot between ε_r tan δ and % of detergent adulterant

The dielectric constant of milk as well as dissipation factor increases approximately linearly as percentage of water adulterant increases correspondingly loss index increases significantly. This study provides some constructive information for developing a fast & accurate sensor in food processing industry.

While in the case of urea, starch and detergent as an adulterant. The dielectric constant of milk as well as dissipation factor decreases significantly as percentage of adulterant increases in steps with correspondingly loss index decreases significantly.

An important point is to be pointed out here is that while using detergent as an adulterant, due to the presence of air bubbles in sample, the system assumes a two phase composition comprising of air and milk .Due to this dielectric constant as well as dissipation factor decreases first and then increases and then decreases.

Through our tests it's clear that milk is not as it should be there for the consumers. It is being adulterated with water, skim milk powder, detergents, salt, urea which have harmful impact on human health. With the complete analysis of the scenario we can conclude that public health is an important issue but adulteration in food is commonly practiced in the market. Consumers are unaware of this and government is doing very less to bring it into notice.

But with proper awareness among the people understanding the criticality of the issue, adulteration can be prevented. If consumers know about the adulteration practices and proper techniques to avoid them, the practice of adulteration would itself be minimized.

Author Contributions:

Mr. Dinku Worku is an early stage researcher and Lecturer at the department of Electrical Engineering, Madda Walabu University, Ethiopia. His research interest include use of robotics in power system, optimization techniques in path planning of robots.

Mr. Marut Dev Sharma is an early stage researcher and Assistant Professor at the department of Electrical Engineering, Madda Walabu University, Ethiopia. He has published 9 peer reviewed research articles, a book and a book chapter. He is a member of the IEEE, IAENG (Hong Kong), MISTE, MISOC (India), and MUACEE (USA). He is certified IT Professional from Microsoft and Cisco (MCSE, CCNA). His research interest includes sensor design, robotic gripper design, and surgical robotics.

Dr. Parmod Kumar is an eminent researcher and Associate Faculty at School of Energy and Electromechanical Engineering, Hunan University Of Humanities, Science and Technology, China. He has published more than 25 peer reviewed research articles.

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Conflicts of Interest: "The authors declare no conflict of interest while performing the research work."

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