ORIGINAL ARTICLE

Milk Adulteration Detection for Added Water by Conductivity

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ABSTRACT This paper describes the different methods which are used for milk adulteration followed by the novel conductivity-based method by which the detection of the milk adulteration can be done. The milk adulteration method works on the principle of electrical conductivity measurement and the popular GERBER method of milk fat detection. The proposed method is the combination of these two methods which gives reliable results for milk adulteration.

Keywords: Milk adulteration, Conductivity, Milkfat, Quality control

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INTRODUCTION

Adulteration of food has increased in every part of the world. There are three main reasons for it. The first reason is the gap between the demand for food and its supply. Due to the limited availability of natural resources, there is always a shortage of certain food items. The second reason is the non-availability of household simple methods to check for adulteration. The third reason is, to earn an additional profit, food adulteration is being done. And it becomes very common in every food item of our day to day life. A large number of testing methods for food adulteration are mentioned in the book "Quick Test for Some Adulterants in Food" (1) published by FSSAI(Food Safety and Standards Authority of India) in the year 2012. However, all the mentioned tests either are chemical based and require skill to perform the experiment, or require complex apparatuses for the method. At the same time, it also requires skilled manpower to handle those apparatuses. Therefore a layman generally cannot perform the tests mentioned in the book.

Milk is one of the most essential food items for our daily requirements. One of the oldest and easiest methods to increase the volume of milk is, adding water to milk as an adulterant to adulterate the milk. As the volume of milk increases. However, now milk adulteration can be detected by the GERBER method (2) based on %fat calculation or by using a lactometer to measure the specific gravity of milk. In the past, electrical conductivity was explored as one of the parameters to detect the water adulteration of milk. However, this parameter was not that much explored in consideration of %fat, protein, %SNF (Solid but Not Fat), and environmental conditions.

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EXISTING NON-CHEMICAL METHODS OF MILK ADULTERATION DETECTION

Till now numerous non-chemical methods had been found for the detection of milk adulteration. A few of the non-chemical methods are NIR (Near Infrared) spectroscopy (3) (4), The FTIR (Fouriour Transform Infrared) Spectroscopy (5), TD-NMR (Time domain Nuclear Magnetic Resonance) spectroscopy (6), the ultrasonic method (7) (8) (9), Enose (10), optical sensrors system (11), and freezing point osmometry (12). All of these methods require complex hardware setup and require understanding and implementation of mathematical algorithms to detect the amount of adulteration in milk. In place of that dielectric properties of milk is easy to measure and neither required any complex sample preparation nor costly instrumental setups.

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The major dielectric properties of milk on which work has been carried out till days are conductance (13), capacitance (14), and impedance phase angle of milk (15). Out of these parameters, the conductivity of milk can be an easy parameter to measure and by measuring conductivity it is possible to detect the adulteration of milk. As in the current situation, there are lots of companies that provide a handheld device to measure conductivity at a higher frequency at an affordable price.

EXPERIMENTS

The conductivity of milk has been explored to measure the presence of water adulteration (13) and the presence of synthetic fat (foreign fat) (16). Though the experiments had given detectable results, the repeatability of the results was not been checked. In the same experiment, it was detected that at the higher frequency the change in detectable output increases too. Therefore to explore conductivity as a parameter to detect the presence of water adulteration, various experiments were carried out.

Experimental Setup

In the presented experiment, the machine setup of HM-Digital company instrument name 'COM-100' was used. It measures the conductivity as well as the temperature of the sample. It gives reading in micro as well as in mili siemence with an accuracy of ±1%. Initially, milk from some of the renowned companies had been taken and their conductivity readings were measured and noted.

Study of Repeatability for the Test Conditions

From the pre-experiments, it was acknowledged that there was a detectable change in the conductivity readings of milk taken from renowned companies. The conductivity readings of the raw milk were measured. In those experiments, cow milk and buffalo milk were taken as samples. The milk %fat was measured by the GERBER method. The fresh milk samples from the same cow and buffalo were taken for the next five days to ensure repeatability. The temperature was kept at 25 ºC using the general purpose water bath while measuring of conductivity of mentioned milk samples.

Raw Milk Conductivity Measurement with Change in Temperature

It is well known that every liquid has temperature dependency while measurement of electrical conductivity. Change in temperature affects the value of reading in almost every kind of liquid or mixture of liquid. To determine the relationship between the conductivity of raw milk and temperature, the sample of raw milk from the cow was heated in a controlled environment using a general purpose water bath. Initially to reduce the temperature of the milk sample the milk was put in the refrigerator. After that for the range of 15 ºC to 40 ºC for a gap of 5 degrees Celsius the conductivity of the milk sample was measured.

Conductivity Measurement with Added Water

Mabrook *et al.* performed the conductivity measurement of water adulteration in milk samples, but the experimental work was done at 8 ºC (14). This temperature cannot be considered room temperature in India. Also, their work was done considering only one type of milk sample. Therefore, expanding their path here we did the measurement of conductivity for the milk sample at 25 ºC by using a general purpose water bath. In the experimental setup, two types of raw milk samples were used to perform the experiment. The first one was raw Buffalo milk having 7.5% fat, and the second one was raw cow milk had 4% fat measured by the GERBER method. As an adulterant the ultrapure water was used which had a conductivity of 0.06 mS (millisiemens). The mixture of milk and water was prepared by keeping the volume of milk and water in a multiplication of 10 while keeping the volume of the sample constant at 100 ml. Hence, total 9 samples with ratio of Milk to Water is 10:90, 20:80, 30:70, 40:60, 50:50, 60:40, 70:30, 80:20 and 90:10 were prepared. The 10^{th} sample was tested without water, i.e., pure milk. To investigate the repeatability of the test result for a firm conclusion, the experiment was repeated for five days by preparing fresh samples from fresh cow and buffalo milk every day keeping the ratio of milk and water as mentioned above. Further, the experiment was done using cow milk and buffalo milk in samples separately. Total 10 samples each day containing cow milk for five days, i.e., 50 samples and 10 samples each day containing buffalo milk for five days, i.e., 50 samples. Hence in this experiment, total of 100 samples were tested. Also, different water conductivity was measured to identify which kind of water accumulates minimum change in the milk sample.

Conductivity Measurement of Mixture made of Buffalo Milk and Cow Milk

With this cow and buffalo fresh milk, one more experiment was performed to check the conductivity response of the sample. The mixture was prepared maintaining ratio as following Table 1. Each time the value of %fat of the milk sample was measured by the GERBER method, and the temperature was sustained at 25 ºC using the water bath.

RESULTS AND DISCUSSION

The results of the study of repeatability for the test conditions

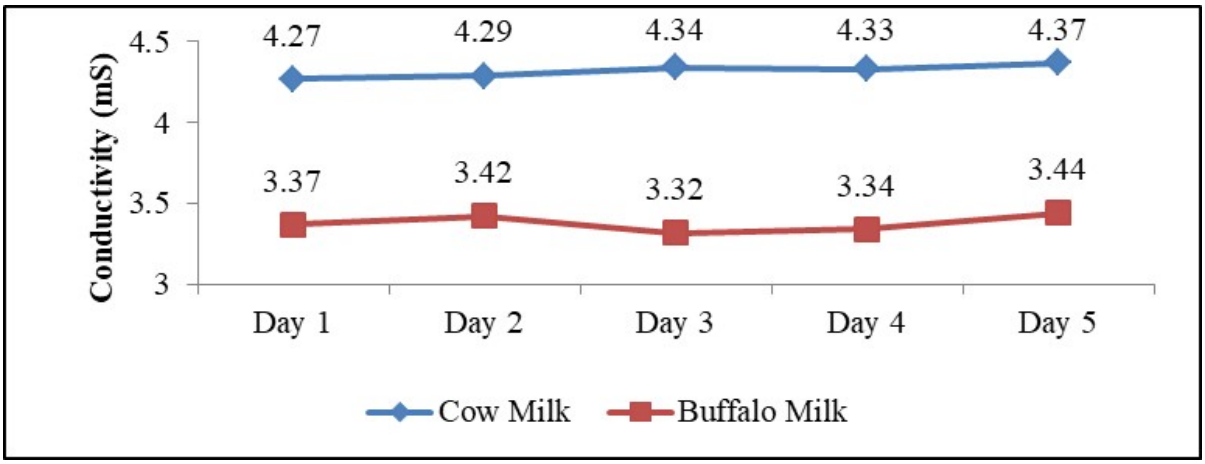
of raw milk conductivity measurements are graphically represented in Graph 1. It is the representation of cow and buffalo milk day wise for the five days. As the results show, at constant fat value the repeatability is ±1% of the reading which shows fairly convincingly that the milk sample has a relationship with conductivity.

Furthermore, the temperature dependency can be derived from the results represented in Graph 2. It illustrates that, as the temperature of milk increases the conductivity of the sample also increases and vice versa.

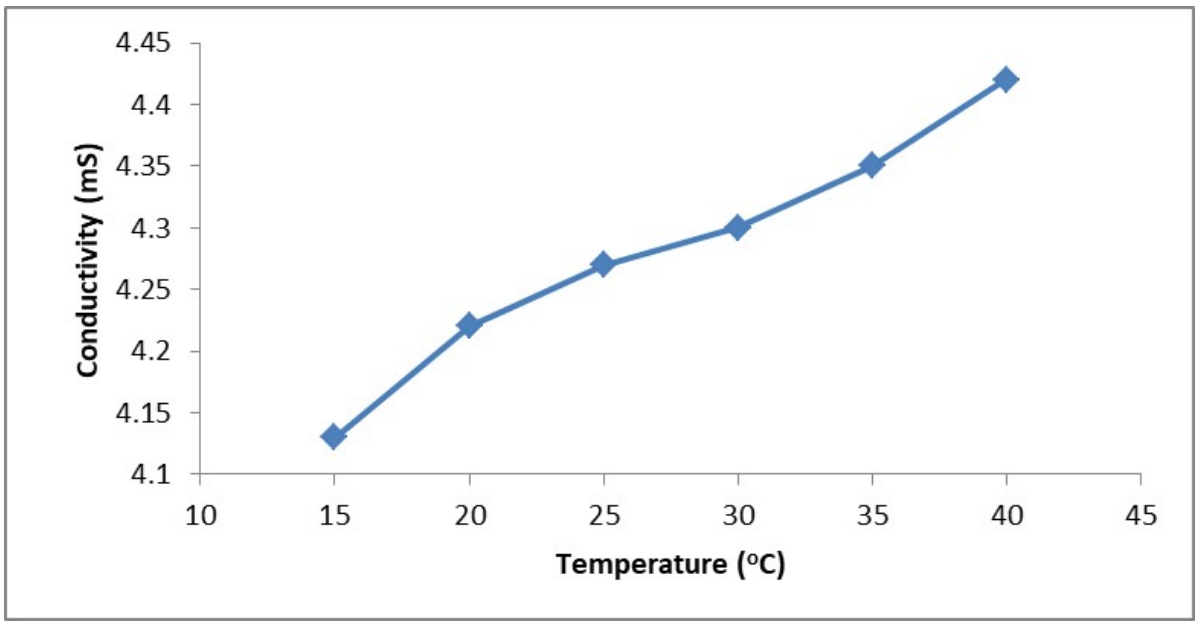
Conductivity readings of adulterated milk with water are graphically represented in Graph 3. It can be noticed that, as the water adulteration increases the conductivity of the milk samples decreases. Form five days measurement values the change in conductivity is calculated around ±1% of the mean measured value. From the number of experiments, it is found that general tap water conductivity is lower than the 9% fat milk. General tap water conductivity lies between 1.2 to 1.6 mS. However, even the 9% fat milk conductivity is around 2.3 to 2.5 mS. Thus if the milk conductivity is lower than 2.2 mS it confirms that the milk is adulterated by the water.

In the last experiment with the different ratios of cow and buffalo milk, the results were derived. Table 1 shows the relationship between the %fat of milk, even when the mixture of milk is being used as a milk sample. The results indicated that as the %fat of the milk increases the value of conductivity

Graph 1: Day Wise Conductivity of Raw Milk Samples



Graph 2: Temperature vs Conductivity of Milk Sample



Graph 3: Day Wise Conductivity of Water Adulterated Samples

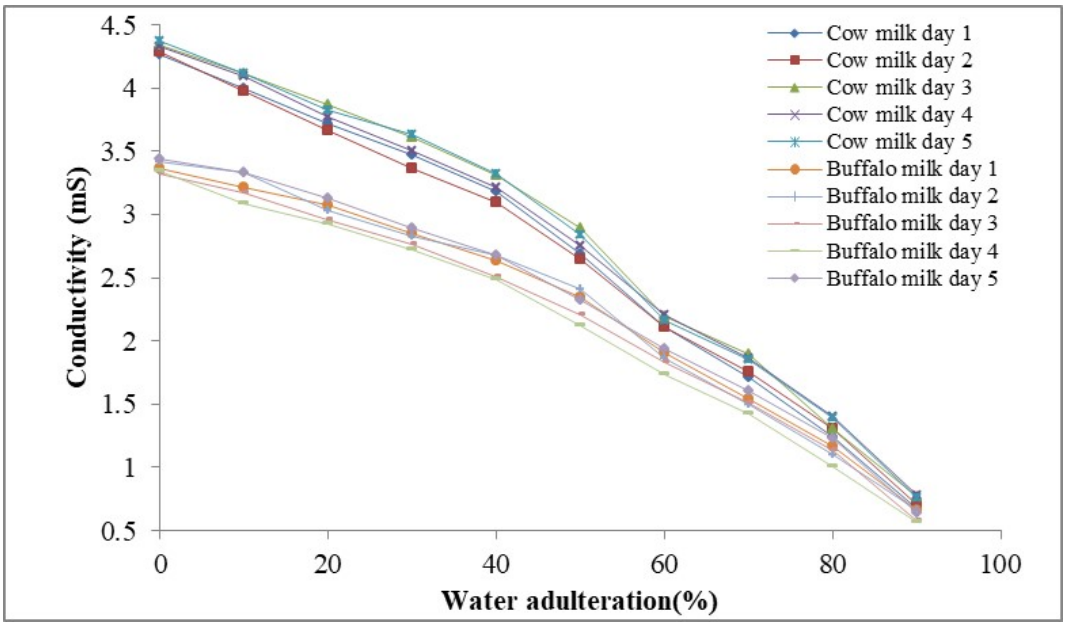


Table 1: Conductivity and Fat Values of Cow and Buffalo Milk Mixture

Cow Milk (ml)	Buffalo Milk (ml)	Conductivity (mS)	% Milk Fat
0	100	3.24	7.5
10	90	3.33	7.2
20	80	3.42	6.8
30	70	3.52	6.5
40	60	3.61	6.1
50	50	3.68	5.8
60	40	3.75	5.4
70	30	3.79	5.1
80	20	3.83	4.7
90	10	3.97	4.4
100	0	4.1	4

decreases. Considering these results and the method implied, a device can be developed to detect the water adulteration in milk.

CONCLUSION

From the results, three things can be concluded. First, as the temperature of the milk sample increases the conductivity of milk also increases. Second, as the value of %fat in the pure milk sample increases the conductivity of the sample decreases. And the third, as the amount of water added to milk increases, it will decrement the milk sample conductivity. Hence considering these three phenomena it is observed that whenever water is added to pure milk as an adulterant, it decreases the reading of the GERBER method value for %fat, and it decreases the value of conductivity too. Hence, by the combination of these two methods, it is possible to detect the added water adulteration in the milk.

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