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Review on conductivity an under-developed method to detect milk adulteration

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ABSTRACT

Milk adulteration is an issue that is continuously increasing. Milk adulteration is done to gain more profits. A general issue of adulteration of any food arises when demand is more than supply. There are many milk adulteration methods. Water adulteration is not only the adulteration used in milk but urea, detergent, foreign fat, neutralizer, flour, and many other methods are used. A single method is not sufficient to detect milk adulteration. However, conductivity and the dielectric property of milk are two main parameters that have been explored for a long time for the detection of milk adulteration. This paper discusses the research works which explored conductivity as a parameter to detect the different types of milk adulteration.

Keywords: Dielectric parameters, Conductivity, Milk adulteration, Phase of angle

INTRODUCTION

Milk is considered one the best food among different food items. Except for the people who are strictly vegan, almost all others consume milk at least once a day in one or another way. The issue didn't get subsidized just by producing a sufficient amount of milk for drinking. But, other dairy products use raw milk as the main ingredient, and hence there is a huge demand for raw milk. There are numerous unconventional methods are being introduced to detect milk adulteration. However, the machinery and equipment used are too costly and require a higher level of knowledge to use such methods. Conductivity is being explored initially to detect the water content in the milk sample (1), since then this parameter is used in one or another way to detect different types of milk adulterants.

The main purpose of adulteration is to increase the important parameter value deciding milk quality such as Percentage of Fat, Protein, and percentage of Solid but Not Fat (SNF). With this parameter in consideration, there is also a requirement to increase the life span of milk. Also in some cases, cattle are given antibodies to produce more milk. And the most common way to increase the volume of milk is by adding water to it. Different classification methods can be used to categorize milk adulteration. This paper presents adulteration methods classification based on the adulterants' potential safety and health hazards to humans.

Types of milk adulteration

Milk Whey, Milk Powder, Water, Different Animal Milk, Vegetable Oil, Starch, and Different types of grains flour are some of the main adulterants which are added to milk, but these milk adulterants are consumed by humans even in direct form. Therefore these adulterants can be counted as less harmful to the human body. On the other hand milk adulterations like Foreign Fat, Detergent, Urea, Neutralizer, Melamine, Shampoo, Food colorants, and preservatives should not be consumed and have an adverse effect on the human body.

There are various methods have been used to detect the mentioned adulterants. One of them is the conductivity of the milk sample. The conductivity of the milk is not constant. The value of conductivity depends on the breed of the cattle, the nutrition of the milk, the health condition of the milking animal, weather conditions, the way milk is been stored, and the lactation period (H, et al., 2014). Even after having many uncontrolled circumstances, a good amount of research work has been done measuring the dielectric properties for the detection of various milk adulteration.

Adulteration detection using different dielectric properties as a measurement variable

The conductivity is basically the dielectric property of milk. The dielectric property measurement can be represented in four ways. These are Resistance, Conductance, Capacitance, and Phase angle of the impedance. These all parameters are related to each other in one or another way. Some of them do have a direct mathematical relationship. So that measuring any one of them elaborates the dielectric property of milk. For the measurement of milk conductivity, there is no specific sample preparation is required. This makes this method convenient and adaptive. The common practice maintained by researchers is to avoid the polarization of the milk sample and measure the conductivity at a higher frequency. In place of measurement of conductance, the phase angle of impedance is measured which also provides the imaginary component of measured resistance. In that way, this method also measures the conductivity of the sample with higher accuracy in terms of phase angle but the method of representation gets changed. In the case of phase angle measurement if the applied frequency is known then the value of the phase angle can be converted to measure the quantity of the adulterant. It is also necessary to maintain frequency at a constant level to achieve a high degree of accuracy.

It can be easily noticed that for the above mentioned parameters in table-1 parameter value decrease with the increase in the %fat of milk. The major milk fat is straight-chain fatty acids that are saturated and have 4 to 18 carbons (4:0, 6:0, 8:0, 10:0, 12:0, 14:0, 16:0, 18:0), monounsaturated fatty acids (16:1, 18:1), and polyunsaturated fatty acids (18:2, 18:3) (Djordjevic, et al., 2019). As carbon fatty acids are resistive in nature to electricity, therefore as the %fat in milk increases, the resistance of the milk sample also increases.

Table 1: %fat relationship with the different parameters of dielectric properties.

Parameter	%fat of milk increases the parameter	Change in measurement with Frequency
Conductance	Decreases	The value increases till 100Hz rapidly, but after that value remains almost constant (De Souza Ribeiro, et al., 2016)
Capacitance	Decreases	The value increases till 1Hz rapidly, but after 10 Hz value starts decreasing very fastly. At 100 Hz Its almost become nearer to zero (De Souza Ribeiro, et al., 2016)
Phase angle of Impedance	Decreases	The value of Phase angle increases with the increment of Frequency rapidly (Dave, et al., 2016)

For almost every common adulterant of milk, there is one or more methods of conductivity measurement exist. All these methods had one cell with two electrodes. The material or metal changes from experiment to experiment. Though the principle for measurements remains the same. Also, almost all experiments were done from lower frequency to high frequency such as 100 kHz to derive better output at a particular frequency.

Table-II: Dielectric parameters measurement to detect different types of milk adulteration

Adulterant Name	Reason to add adulterant	Effects on human body	Measured Dielectric Parameter	Change with Amount of Adulterant Increases	Change in measurement with Frequency
Water	To increase the volume of milk	Reduction of nutrition	Conductance	Conductance Decreases	The conductance increases till 100Hz rapidly, but after that value remains almost constant (Mabrook, et al., 2003)
			Susceptance	Susceptance Decreases	The susceptance increases till 1Hz rapidly, but after 10 Hz susceptance starts decreasing very drastically. At 100 Hz Its almost become nearer to zero (Mabrook, et al., 2003)
			Phase angle of impedance	Phase angle Decreases	Phase angle decreases with increment in frequency very gradually (Das, et al., 2011)

Starch	To increase the value of %SNF in milk	Diarrhea and Fatal to Diabetic patients	Resistance	Resistance Increases	From 1 to 40 kHz the resistance decreased and then from 40 kHz to 100 kHz the value increased (Sude, et al., 2019)
			Phase angle of impedance	Phase angle Increases	The phase angle increases till 90Hz rapidly (Sude, et al., 2019)
Urea	To increase the value of %SNF in milk	Damage to kidney	Resistance	Resistance Decreases	From 1 to 100 kHz the resistance remains almost constant (Sude, et al., 2019)
			Conductance	Conductance Increases (Das, et al., 2011)	-
			Phase angle of impedance	Phase angle Increases	The phase angle increases till 90Hz rapidly (Sude, et al., 2019)
Whey	To increase the volume of milk	Digestive distress, fatigue, nausea, and poor appetite	Phase angle of impedance	Initially impedance decreases after more than 60% adulteration it increases	Phase angle decreases very gradually over a range of 1 kHz to 20 kHz (Das, et al., 2009) (Das, et al., 2011)
			Conductance	Conductance increases (Das, et al., 2011)	-
Hand wash, Shampoo, Detergent	To increase the value of %SNF and thickness of milk, an Emulsifier of vegetable oil fat	Problems related to the gastro-intestinal system and the kidney	Conductance	Conductance Increases (S, et al., 2018)	-
			Phase angle of impedance	Phase angle Increases (S, et al., 2018)	-
Foreign Fat	To increase the value of %FAT of milk	Can cause Cancerous effects on the human body	Conductance	Conductance Decreases	The conductance increases till 100Hz rapidly, but after that conductance remains almost constant (Sadat, et al., 2006)
			Capacitance	Capacitance Decreases	The capacitance increases till 1Hz rapidly, but after 10 Hz capacitance starts decreasing very drastically. At 100 Hz Its almost become nearer to zero (Sadat, et al., 2006)

Formaline	To increase the lifetime of milk	Poisonous to the human body	Phase angle of impedance	Phase angle Increases	The experiment was done for a range of 1 HZ to 10 kHz Value of Phase angle increases with the increment of Frequency rapidly (Chakraborty, et al., 2018)
Ammonium sulphate	To increase the lifetime of milk	An extra amount of Sodium can be dangerous to the Heart and High BP patients	Phase angle of impedance	Phase angle Increases	
Sodium hydroxide	To increase the lifetime of milk		Phase angle of impedance	Phase angle Increases	
Sodium bi-Carbonate	To increase the lifetime of milk		Phase angle of impedance	Phase angle Increases	
Salt (NaCl)	To increase the value of %SNF in milk		Phase angle of impedance	Phase angle Increases	

CONCLUSION:

The extensive research based on dielectric parameter measurement as explained above is carried out by various researchers to detect milk adulteration. It is observed that they have used different types of electrodes to measure dielectric parameters at high frequencies. However, the accuracy of measurement is heavily dependent on the variability of other uncontrolled parameters and situations. It is also necessary to initially developed a model, considering the variability of the other parameters and situation. Therefore, it becomes necessary to produce a huge database relating dielectric parameters to pure milk and adulterated milk with various types of and various amounts of adulterants.

The dielectric parameters measurement methods to measure the milk parameters are complex in presence of other variabilities, which is further becoming very complex in presence of above discussed adulterant to increase the value of the percentage of Fat, Protein, and percentage of SNF. It is possible to develop an intelligent module to accurately measure the conductivity of the milk at a particular frequency and electrodes for the measurement of three important milk parameters having compensation of ambient temperature, milk temperature, and another variability. This will standardize the conductivity measurement for the detection of adulterant presence in the milk.

However, only using conductivity as a measuring parameter is not sufficient to identify all types of adulterants and their amount present in milk. Hence, multiple methods can be combined with conductivity measurement to ensure the detection of the type of adulterant and its amount.

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