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# Detection of Milk Adulteration Using Ultrasonic Measurements

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**Abstract:** Checking adulteration in milk is essential because it is a vital component of the human diet and the practice of adulteration by milk vendors is going on for a long time. This experiment aims at calculating the velocity of ultrasonic waves in milk with adulterants by a non-destructive method. Lactometer can also be used for this purpose but the drawback of this method (Lactometer) is the requirement for the sample to be in large quantity as compared to the presently proposed method (i. e Ultrasonic Interferometer) which needs just 10ml of the sample. Even there are some other chemical methods for this purpose but the addition of chemicals may ruin the milk. Hence, we can say that ultrasonic measurements are more convenient. The adulterants used in the present study are water (10%, 20%, 30%, 40%, and 50%) by volume and other common milk adulterants such as Sodium Carbonate, Sodium Bicarbonate, Formalin, Urea with an addition of 2%, 4%, 6%, 8%, 10% by volume. The trend in the change of ultrasonic velocity, density, adiabatic compressibility, acoustic impedance, intermolecular free length and surface tension. It was found that ultrasonic velocity shows a significant dependence on the different types of adulterants. The study indicates that there is ample scope to design an ultrasonic interference-based sensor to detect milk adulteration.

**Keywords:** Milk Adulteration, Ultrasonic Waves, Interferometer, Adulterants, Ultrasonic Sensor

## 1. Introduction

Food is said to be adulterated if its quality is lowered or affected by the addition of substances that are harmful to health or by the removal of substances that are nutritious. Adulteration of milk with lower-priced materials is common everywhere in the world. Some adulterants are very harmful to human health. In the contamination of milk, brokers likewise play a significant part. The milk used for utilization by people is defiled so much that it has almost no health benefit and may become harmful to their well-being. Milk sellers gain profit by removing milk fat as cream and adding starch to increase the density of the milk [1]. One of the very oldest forms of milk adulteration is by adding variable volumes of water for high profit. This not only decreases the nutritional value of milk but also if the water added is contaminated there is a high risk to human health because of waterborne diseases [2]. Milk is also adulterated with some chemicals other than water. Some of the chemicals are Sodium Carbonate, Sodium bicarbonate, Urea, Formalin, Melamine, Hydrogen peroxide, Starch, Chlorine, Sugars, Neutralizers, Food colors, whey, preservatives, Non-milk protein fats, milk powder, etc. A few adulterants, like detergents, are utilized to give the milk a foamy appearance. At the point when water is mixed in milk, its frothy appearance reduces, so fake detergents are applied to it to give the milk a frothy appearance. To brighten the milk, hair expulsion powders, and urea are applied to give it a veritable look. Only a couple of grams of urea is satisfactory to return milk once again to its unique state. Throughout the summer season, hydrogen peroxide is normally used to save milk when the encompassing temperature is extremely high. These adulterants are very hazardous to human health. They cause heart diseases, kidney failures, liver diseases, acidity, indigestion, ulcers, cancer, damage to gastrointestinal cells,

early aging, food poisoning, etc. So it is very important to check for adulteration in milk before consuming it [1].

### *1.1. Literature Survey*

Many researcher [3-8] have reported their studies on the milk adulteration and different techniques to determine various types of adulteration in milk. Indu Saxena et al., [9] worked on the experimental techniques in the measurement of ultrasonic velocity, density, and viscosity and discussed the working principle of the ultrasonic interferometer. An Ultrasonic Interferometer is a simple and direct device to determine the ultrasonic velocity in liquid with a high degree of accuracy. In an ultrasonic interferometer, the ultrasonic waves are produced by the piezoelectric methods. Ultrasonic waves of known frequency are produced by a quartz crystal which is fixed at the bottom of the cell. At a fixed frequency variable path interferometer, the wavelength of the sound in an experimental liquid medium is measured, and from this one can calculate its velocity through that medium.

Mohammed Habib Ali et al., [10] used the ultrasonic interferometer to find the change in the velocity of ultrasonic waves and the density of milk when it is adulterated with water. And the conclusion he drew was that both the density of milk and the ultrasonic velocity linearly decreases with the % of adulteration of water. The relationship between the parameters under study and % of water adulterated to milk is strong as the $R^2$ value is more than 0.9 in all the cases.

### *1.2. Objective*

To overcome the drawbacks faced during the usage of the lactometer and chemical methods, we need an easy and non-destructible method to check the purity of milk. Ultrasonic Interferometer is a simple, direct, and non-destructive device used to determine the ultrasonic velocity in liquids. Based on the change of the ultrasonic velocity during the addition of adulterants in different percentages, we can try to check the purity of milk. The aim of this paper is to record the value of ultrasonic velocity in milk with the addition of different adulterants such as milk, sodium carbonate, sodium bicarbonate, urea, and formalin. Also, to calculate adiabatic compressibility, acoustic impedance, intermolecular free length, and surface tension which are related to ultrasonic velocity and density. And to comment on adulteration in the milk sample.

## 2. Methods and Materials

The important parts of the ultrasonic interferometer used in present study are quartz crystal, high-frequency generator, ammeter, measuring cell, and reflector. When the electric field is applied to the interferometer, the quartz crystal starts vibrating and this produces a progressive wave. The progressive wave moves through the liquid and hits the reflector. This again produced a reflected wave. These two waves interfere and then produce a standing wave. And the standing wave produced here is an ultrasonic wave. To calculate the velocity of the ultrasonic waves, we measure their wavelength. To perform the experiment selection of the correct measuring cell is very important. The deflection in the ammeter is not observed for all the cells. This is because the standing wave is formed only when the reflected wave and the progressive wave have the same frequency. The proper measuring cell makes sure that this happens. For milk such frequency is 2MHz. After the selection of the measuring cell, 10 ml of the sample is poured into it. The micrometer is rotated to find the position such that the separation between the plates is exactly an integer multiple of half wavelength of sound. Under these circumstances, acoustic resonance occurs. The resonant waves are maximum in amplitude, causing a corresponding maximum in the anode current of the piezoelectric generator. By rotating the micro-meter the difference between two such positions is measured which gives the value of λ/2. Using the value of wavelength and the frequency, the velocity (u) of the ultrasonic wave is calculated. The mass of the sample of known volume is measured and using these two the density (ρ) of the sample is also calculated. Adiabatic compressibility is calculated using the Newton-Laplace formula;

$$\beta = \frac{1}{u^2\rho} Kg^{-1}ms^2$$

The acoustic impedance is given by the relation;

$$Z = u\,\rho\ \mathrm{Kg/m^2s}$$

The intermolecular free length is related to adiabatic compressibility as [10];

$$L_f = k_T\sqrt{\beta}\, m$$

where $k_T = 199.5\times10^{-8}$ and this is temperature dependent constant.

The relationship between the surface tension, density and ultrasonic velocity is given by J D Pandey and G P Dubey as [11];

$$\sigma_m = 6.3 \times 10^{-4}\rho u^{\frac{3}{2}}\ \mathrm{N/m}$$

## 3. Results and Discussion

***Table 1.*** *Comparison of ultrasonic velocities in pure milk from literature and present results.*

| **Ultrasonic velocity (m/s)** | | |
|---|---|---|
| **From [12]** | **From [9]** | **Present results** |
| 1522 | 1524 | 1508 |

***Table 2.*** *Values recorded when milk is mixed with water.*

| water % | u (m/s) | ρ (kg/m$^{3}$) | β in $10^{-10}$ (Kg$^{-1}$ms$^{2}$) | Z (Kg/m$^{2}$s) | $L_f$ in $10^{-11}$ (m) | σ (N/m) |
|---|---|---|---|---|---|---|
| 0 | 1508 | 1035.24 | 4.25 | 1561141.92 | 4.11 | 38192.99 |
| 10 | 1496 | 1033.09 | 4.33 | 1545502.64 | 4.15 | 37659.63 |
| 20 | 1460 | 1028.25 | 4.56 | 1501245 | 4.26 | 36138.37 |
| 30 | 1456 | 1020.77 | 4.62 | 1486241.12 | 4.29 | 35728.15 |
| 40 | 1452 | 1007.4 | 4.71 | 1462744.8 | 4.33 | 35114.98 |
| 50 | 1428 | 994.47 | 4.93 | 1420103.16 | 4.43 | 33808.39 |

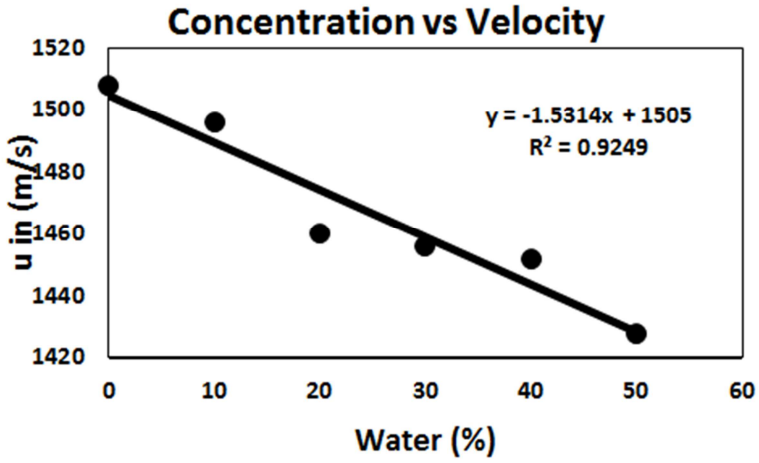


***Figure 1.*** *Concentration vs Velocity graph for (milk + water).*

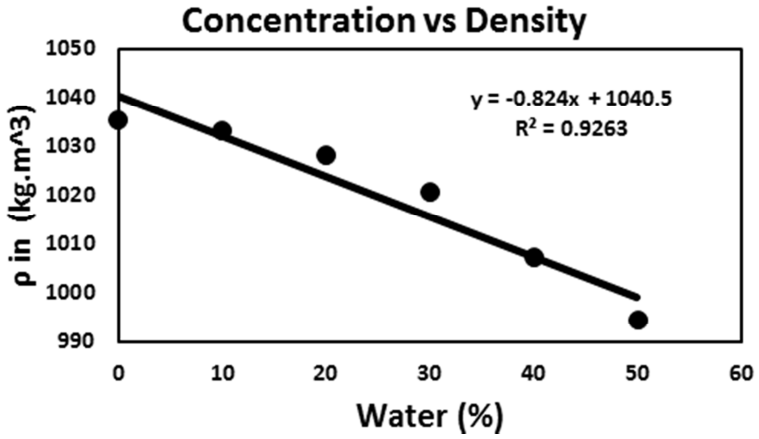


***Figure 2.*** *Concentration vs Density graph for (milk + water).*

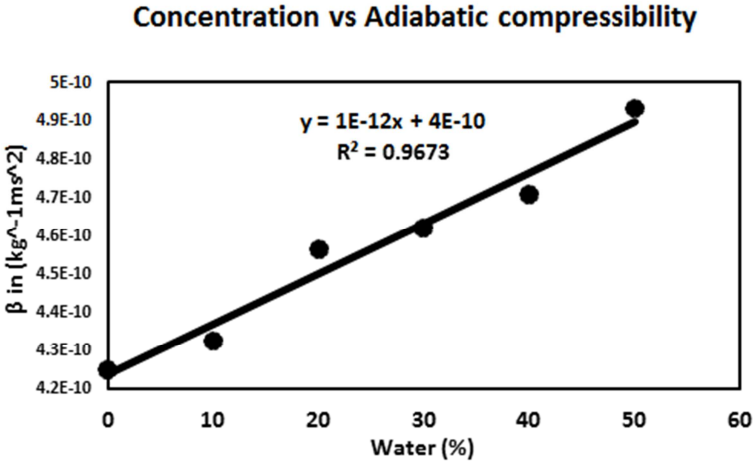


***Figure 3.*** *Concentration vs Adiabatic compressibility for (milk + water).*

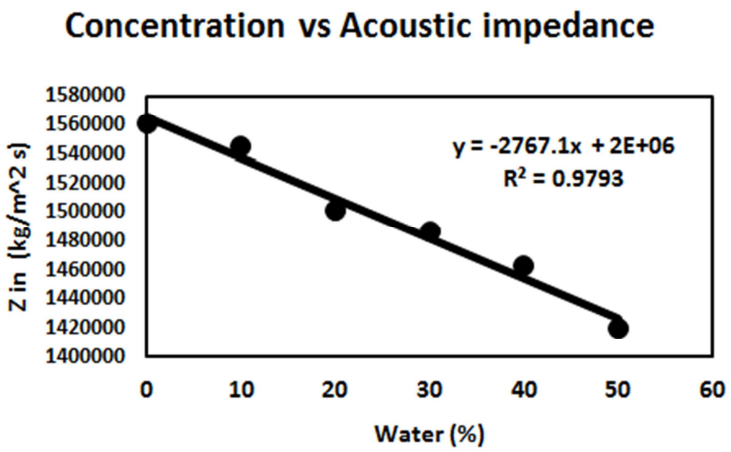


***Figure 4.*** *Concentration vs Acoustic impedance graph for (milk + water).*

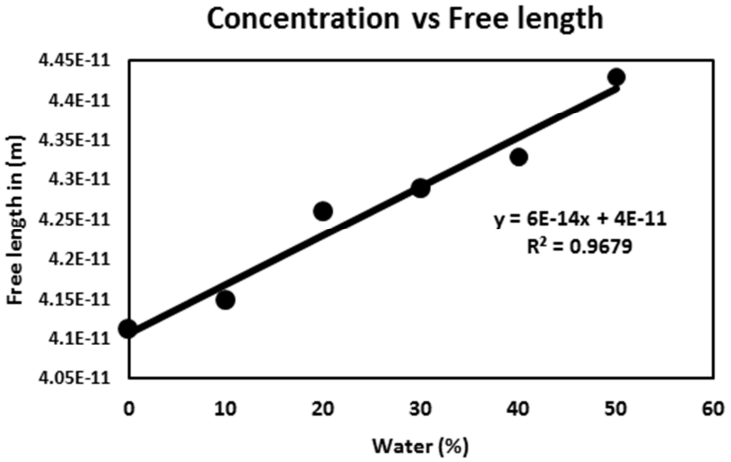


***Figure 5.*** *Concentration vs Free length graph for (milk + water).*

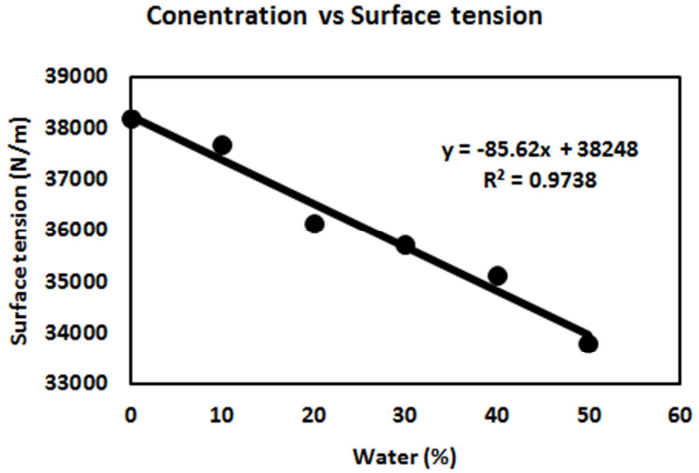


***Figure 6.*** *Concentration vs Surface tension graph for (milk + water).*

***Table 3.*** *Values recorded when milk is mixed with sodium carbonate and water.*

| ($Na_2CO_3$ + water) % | u (m/s) | ρ (kg/m$^3$) | β in $10^{-10}$ ($Kg^{-1}ms^2$) | Z ($Kg/m^2s$) | $L_f$ in $10^{-11}$ (m) | σ (N/m) |
|---|---|---|---|---|---|---|
| 0 | 1508 | 1035.24 | 4.25 | 1561141.92 | 4.11 | 38192.99 |
| 2 | 1492 | 1033.23 | 4.33 | 1541579.16 | 4.16 | 37513.78 |
| 4 | 1488 | 1028.97 | 4.39 | 1531107.36 | 4.18 | 37208.97 |
| 6 | 1480 | 1019.75 | 4.48 | 1509230 | 4.22 | 36578.58 |
| 8 | 1468 | 992.14 | 4.68 | 1456461.52 | 4.31 | 35156.25 |
| 10 | 1592 | 1091.63 | 3.61 | 1737874.96 | 3.79 | 43684.83 |

***Table 4.*** *Values recorded when milk is mixed with sodium bicarbonate and water.*

| ($NaHCO_3$ + water) % | u (m/s) | ρ ($kg/m^3$) | β in $10^{-10}$ ($Kg^{-1}ms^2$) | Z ($Kg/m^2s$) | $L_f$ in $10^{-11}$ (m) | σ (N/m) |
|---|---|---|---|---|---|---|
| 0 | 1508 | 1035.24 | 4.25 | 1561141.92 | 4.11 | 38192.99 |
| 2 | 1464 | 1020.74 | 4.57 | 1494363.36 | 4.27 | 36021.96 |
| 4 | 1460 | 1015.23 | 4.62 | 1482235.8 | 4.29 | 35680.77 |
| 6 | 1452 | 1011.8 | 4.69 | 1469133.6 | 4.32 | 35268.35 |
| 8 | 1472 | 1052.36 | 4.39 | 1549073.92 | 4.18 | 37442.65 |
| 10 | 1528 | 1082.26 | 3.96 | 1653693.28 | 3.97 | 40724.63 |

***Table 5.*** *Values recorded when milk is mixed with urea and water.*

| (urea + water) % | u (m/s) | ρ ($kg/m^3$) | β in $10^{-10}$ ($Kg^{-1}ms^2$) | Z ($Kg/m^2s$) | $L_f$ in $10^{-11}$ (m) | σ (N/m) |
|---|---|---|---|---|---|---|
| 0 | 1508 | 1035.24 | 4.25 | 1561141.92 | 4.11 | 38192.99 |
| 2 | 1498 | 1033.58 | 4.31 | 1548302.84 | 4.14 | 37753.08 |
| 4 | 1484 | 1030.47 | 4.41 | 1529217.48 | 4.19 | 37113.06 |
| 6 | 1480 | 1025.23 | 4.45 | 1517340.4 | 4.21 | 36775.15 |
| 8 | 1540 | 1080.96 | 3.90 | 1664678.4 | 3.94 | 41155.82 |
| 10 | 1544 | 1095.75 | 3.83 | 1691838 | 3.90 | 41881.57 |

***Table 6.*** *Values recorded when milk is mixed with formalin.*

| formalin % | u (m/s) | ρ ($kg/m^3$) | β in $10^{-10}$ ($Kg^{-1}ms^2$) | Z ($Kg/m^2s$) | $L_f$ in $10^{-11}$ (m) | σ (N/m) |
|---|---|---|---|---|---|---|
| 0 | 1508 | 1035.24 | 4.25 | 1561141.92 | 4.11 | 38192.99 |
| 2 | 1500 | 1029.58 | 4.32 | 1544370 | 4.14 | 37682.31 |
| 4 | 1496 | 1023.91 | 4.36 | 1531769.36 | 4.17 | 37324.99 |
| 6 | 1488 | 1006.34 | 4.49 | 1497433.92 | 4.23 | 36390.64 |
| 8 | 1448 | 1003.28 | 4.75 | 1452749.44 | 4.35 | 34826.96 |
| 10 | 1484 | 1005.63 | 4.52 | 1492354.92 | 4.24 | 36218.43 |

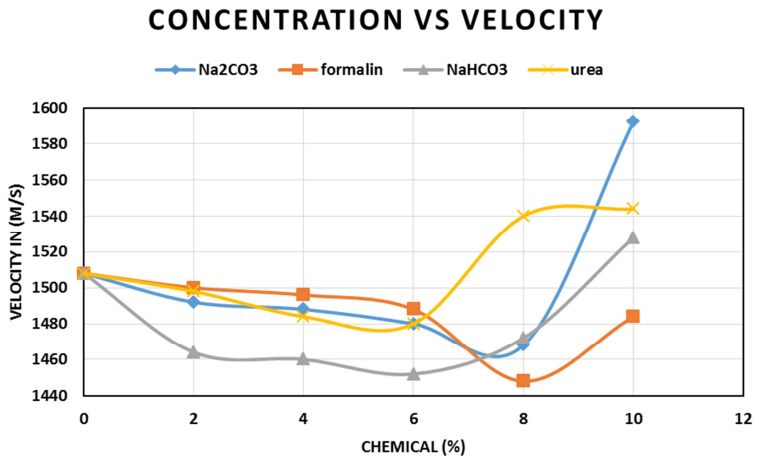


***Figure 7.*** *Concentration vs Velocity for $Na_2CO_3$, formalin, $NaHCO_3$, urea as adulterant.*

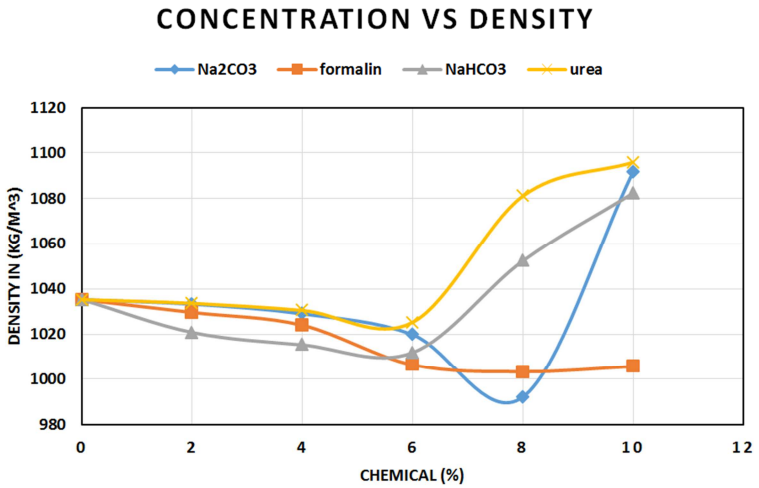


***Figure 8.*** *Concentration vs Density for $Na_2CO_3$, formalin, $NaHCO_3$, urea as adulterant.*

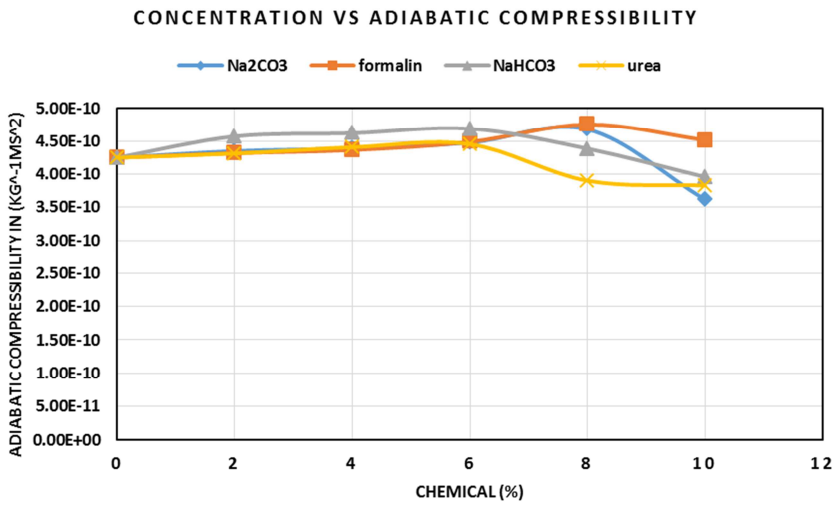


***Figure 9.*** *Concentration vs Adiabatic compressibility for $Na_2CO_3$, formalin, $NaHCO_3$, urea as adulterant.*

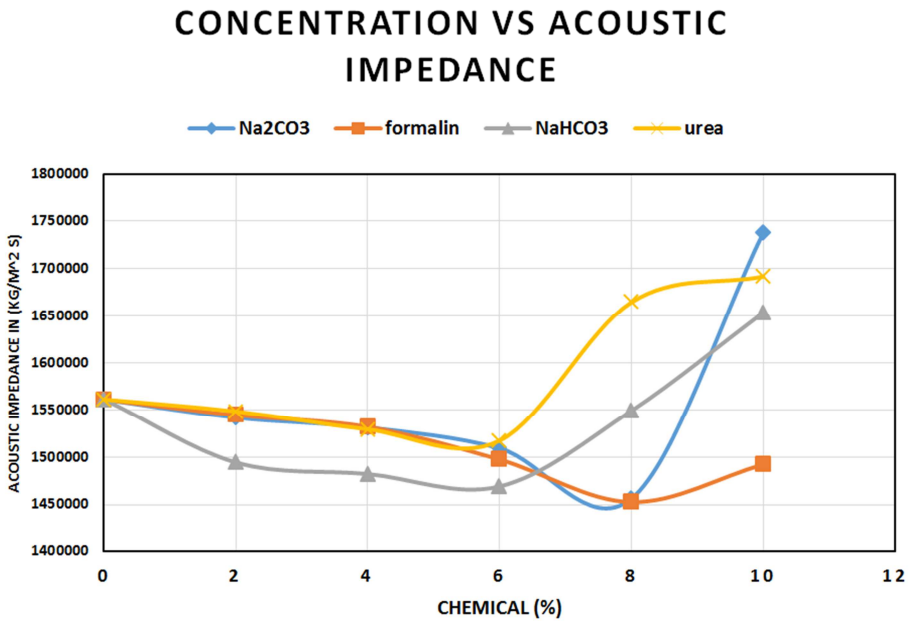


***Figure 10.*** *Concentration vs Acoustic impedance for $Na_2CO_3$, formalin, $NaHCO_3$, urea as adulterant.*

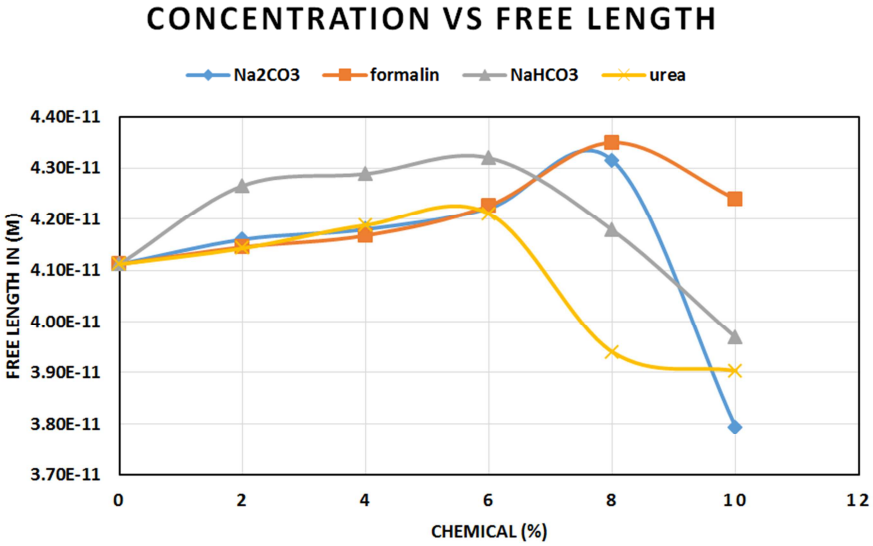


***Figure 11.*** *Concentration vs Free length for $Na_2CO_3$, formalin, $NaHCO_3$, urea as adulterant.*

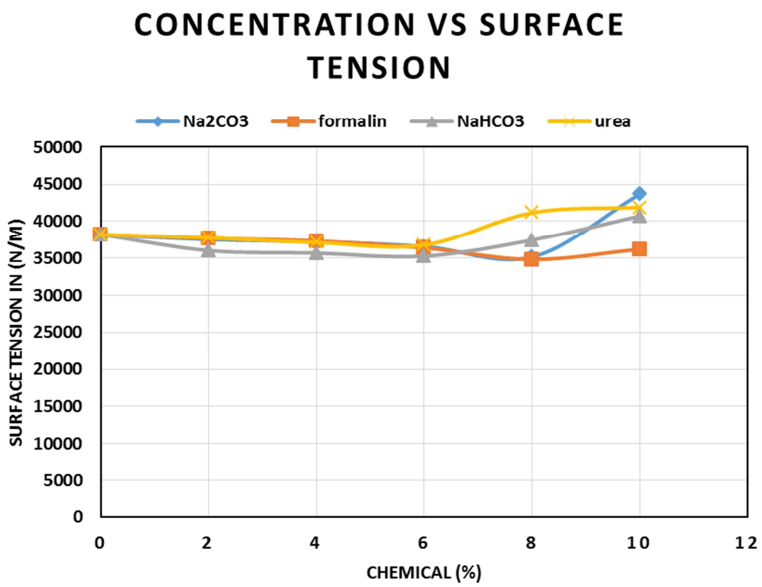


***Figure 12.*** *Concentration vs Surface tension for $Na_2CO_3$, formalin, $NaHCO_3$, urea as adulterant.*

It is seen that the density and ultrasonic speed decreases linearly, as we increase the % of water in the unadulterated milk. The ultrasonic velocity and density are more for pure milk. The addition of water leads to a decrease in intermolecular forces between protein particles present in the milk. The value of ultrasonic velocity decreases due to weak interaction between the milk component and water molecule. Lower values of surface tension with increasing concentration are responsible for weak interaction in the mixture which is due to the hydrophobic nature of protein and fat molecules present in milk. The acoustic impedance decreases with the addition of water in the pure milk. This is due to the breaking of bonds present in the milk protein and represents weak interactions between solute-solute components present in the solution. The values of adiabatic compressibility and intermolecular free length increase with increasing water molecule concentration due to weak interaction. As water is added to the pure milk, proteins get solvated, and hence intermolecular forces of attraction become weak due to the splitting of milk proteins [13].

If we consider the reaction of milk with the other chemicals, at first there is a decrease in the ultrasonic velocity and density because of the water content added in the adulterant. But as we keep increasing the concentration of the adulterant, there is a sudden spike in the ultrasonic velocity and density because of the bonds formed between the milk and the chemicals dominate the effect of water on milk. The increase in ultrasonic velocity is due to the strong dipole-dipole interaction or hydrogen bond complex formation between the proteins molecules and other components present in the milk with the chemicals added [14]. Ultrasonic sensing system for detecting water adulteration in milk is suggested by [15].

## 4. Conclusion

According to the results obtained from the present work, ultrasonic propagation velocity was found helpful to identify adulteration in milk. It is found that the addition of water as the adulterant leads to a decrease in the ultrasonic velocity and the addition of the chemicals as the adulterant at first leads to a decrease in the ultrasonic velocity because of the dominance of the water over the chemicals and later there is a sudden increase in the ultrasonic velocity. By analyzing the results obtained we can conclude that the ultrasonic waves are very sensitive even for the slightest amount of adulteration added. So we can say that the change in the velocity due to the adulterants can be used to detect and estimate the adulteration in the milk. The proposed method just uses 10ml of the sample which is also reusable and hence causes less or no wastage. From present studies, we can say that ultrasonic approach can be used to prepare a micro ultrasonic sensor to find adulteration in milk.

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