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Non Destructive Testing of Milk adulteration using Ultrasound

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ABSTRACT

Objectives: A non-destructive testing setup is developed using a 1 MHz ultrasonic transducer and tested for identifying the adulteration in milk. For this study we have used water, urea and sugar as adulterants. Ultrasonic velocity is measured for samples prepared with adulterants in milk. It is shown that ultrasonic velocity is varying with adulteration. Ultrasonic velocity obtained for pure milk, milk + 10% water + .25g/10ml of sugar and milk + 10% water + .25g/10ml of urea are 1522 m/s, 1527 m/s and 1529 m/s, respectively. The ultrasonic velocity of milk adulterated with sugar and urea shows higher ultrasonic velocity than pure milk with the same density values. This method can be used for online monitoring the quality of milk the in a large scale to avoid adulteration of milk.

Keywords: Adulteration, Chemical Additives, Milk, Ultrasound Velocity.

1. INTRODUCTION

Milk is essentially an emulation of fat and protein in water. A typical sample of milk is composed of 3.5% fat 3.2% protein and 85% of water. The adulteration of milk means addition of prohibited substance for financial gain. Milk is mainly adulterated with water, urea, salt and sugar. This may endanger the consumer health. In the consumer milk industry conventional adulteration detection is based on density measurement which is mainly used to measure the amount of water present in the milk. The decrease in density of milk due to water adulteration can be compensated by adding some amount of sugar or urea. This makes density measurement insufficient for detection of chemical additives. In this work, an ultrasonic sensor is employed to detect the adulteration of milk with sugar and urea.

Many researchers theoretically and experimentally explained the effect of particle velocity on propagation of sound through liquids. [1-3]. McClements et al [4] discussed about applications of ultrasound in food analysis and processing. Mohanan et al [5] reported detection of chemical additives in milk but implementation in the online system is not discussed. They used ultrasonic interferometer for velocity measurement. Adamowski et al [6] developed an online density measurement system. Higuti *et al* [7-8] and Bjørndal et al [9] modified the measuremnt system developed by Adamowski et al and measured ultrasonic parameters of liquids.

Later, Nazário *et al*[10] proposed a method for milk adulteration detection using ultrasound and neural network in which requires prior training for the network for the prediction of adulteration percentage. However, in their works for detection of water content by maintain the same density by added urea or sugar in milk is not discussed. In this work, we propose a method to detect this using ultrasonic velocity.

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2. THEORY OF PROPAGATION OF ULTRASOUND IN MILK

Ultrasound velocity is very sensitive to intermolecular interactions and molecular organisation, which make ultrasound velocity measurements suitable for determining the physical state, structure, composition and various molecular processes. When an ultrasound beam comes in contact with an interface, it is partly transmitted and partly reflected.

Acoustic impedance z for a wave in a less absorbing medium is the product of density and velocity of sound in that medium.

$$z = \rho c \qquad (1)$$

where z is the acoustic impedance for a wave in a medium (Pa s/m^3), ρ is the density (kg/m^3) and c is the velocity of propagation (m/s).

Ultrasonic velocity in a medium can also be determined using Newton–Laplace equation,

$$c = \sqrt{\frac{E}{\rho}} \qquad (2)$$

where E is the Elastic modules.

The woods equation shows the link between velocity of sound and density of solution:

$$c = \frac{1}{\sqrt{k\rho}} \qquad (3)$$

where k is the adiabatic compressibility.

3. ULTRASONIC VELOCITY MEASUR-EMENT SYSTEM.

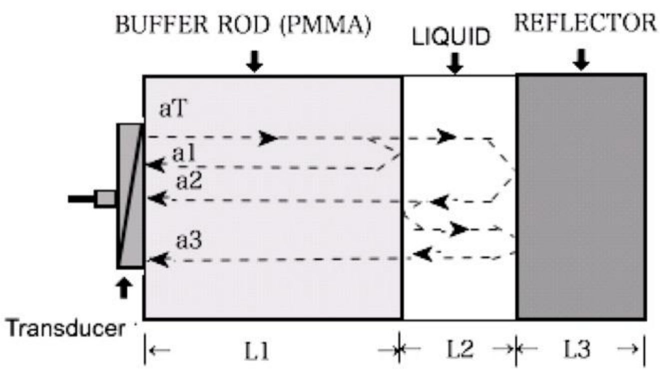

Figure 1. Schematic diagram of the measurement cell.

Schematic diagram of the measurement cell is shown in figure 1. Poly methyl methacrylate (PMMA) is used as a buffer rod for ultrasonic transducer. L1 is the length of the buffer rod and L2 is the distance between the buffer rod and steel reflector. Ultrasonic transducer is fixed to PMMA using a clamp. Silicon glue is used as coupling material between transducer and PMMA buffer rode for propagation of ultrasonic pressure waves.

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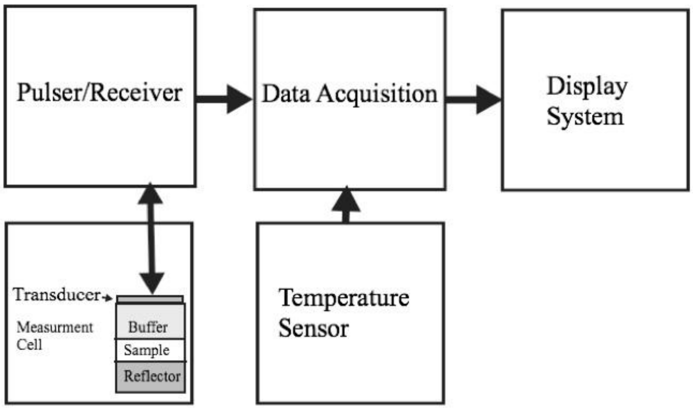

Figure 2. Block diagram of experimental setup.

Block diagram of the experimental setup for measuring the ultrasonic parameters is shown in Figure 2. Ultrasonic transducer (1 MHz, Olympus V303) is used to generate 1 MHz pulse signal. Pulser/receiver (Olympus 5077PR) provides high voltage pulse required by ultrasonic transducer as well as amplification and filtration before the analogue signal passed to data acquisition device (Agilent 6012A). To measure the sample temperature a thermocouple is connected to a data acquisition system ((NI cDAQ-9172 with NI 9211). Real time data is acquired in the computer using LabVIEW 2013 and the velocity is calculated with respect to temperature.

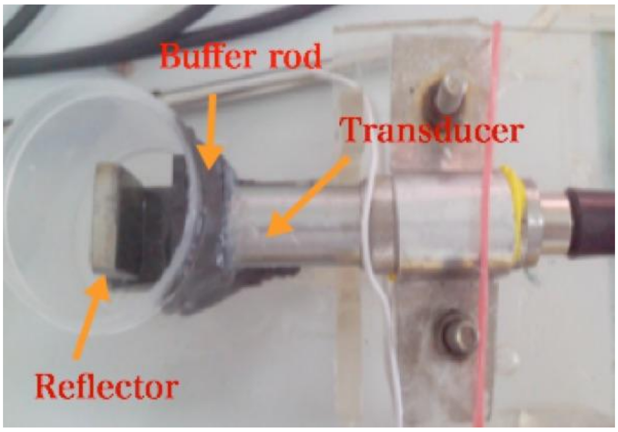

Figure 3. Measurement Cell with Transducer.

Ultrasonic measure cell consists of reflector and ultrasonic transducer attached to buffer rod is inserted to plastic cup Figure 3.

In the case of food quality analysis and processing using ultrasound the hygienic design of measurement cell was the major constraint. The proposed arrangement minimizes the fouling layer formation, bubble strapping and easy cleaning of cell. Temperature controlled water bath consists of immersion heater with thermostatic control and thermocouple for temperature measurement as shown in figure 4. Figure 5 shows the sample ultrasonic waveform to be used for the detection of adulteration obtained using this setup.

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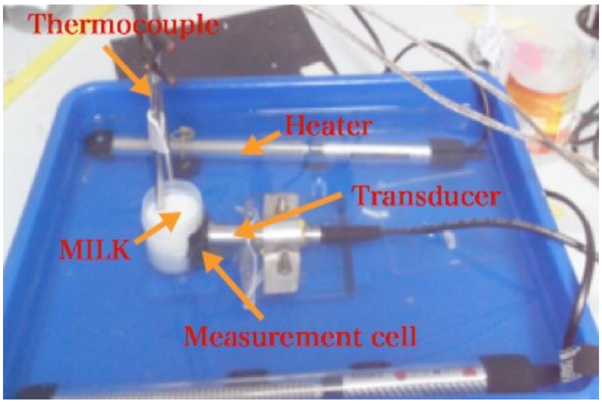

Figure 4. Measurement Cell inside water bath.

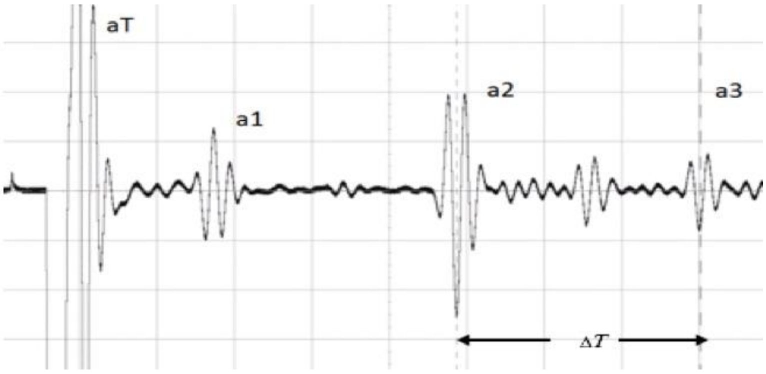

Figure 5. ΔT measurement between a_2 and a_3 from reflections.

The transmitted ultrasonic wave aT which propagates through the cell, when it reaches at the interface of liquid and buffer, a portion of aT is reflected and recorded as a1 and remaining is transmitted through the liquid which is again reflected back at the interface of liquid and reflector. A portion of this reaches the transducer as a2 signal and other portion is reflected at buffer and liquid interface to reflector and return back to the transducer as a3 signal. Velocity (m/s) is calculated with ΔT measured between a2 and a3 where, a2 and a3 are the second and third reflections in the measurement cell.

$$Velocity = \frac{2L_2}{\Delta T} \quad (4)$$

Where L_2 is the distance between buffer rod and reflector. The wave form is acquired in digital storage oscilloscope and personal computer as shown in experimental setup Figure 6.

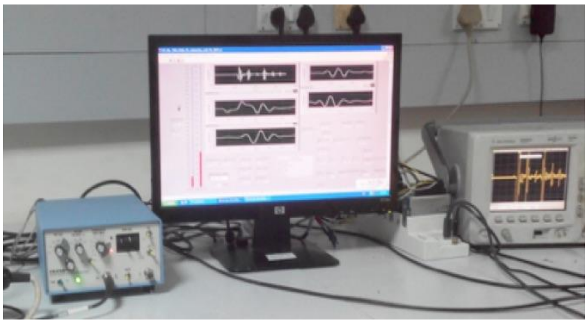

Figure 6. Real time measurement using LabView and Digital storage oscilloscope.

4. RESULTS AND DISCUSSION

4.1 Pure milk with water as adulterent

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Effect of ultrasonic velocity with respect temperature for 0%, 10%, 20%, 30%, 40%, 50% and 100% of water mixed with milk at 30 to 40 degrees Celsius shown in the Figure 7 It shows a decrease in velocity with increase in water content and an analysis of velocity with temperature for 0%,10%,20%,30%,40%,50% and 100% reveal an upward shift. This shows that viscous and thermal effect of milk depends on thermo-physical properties.

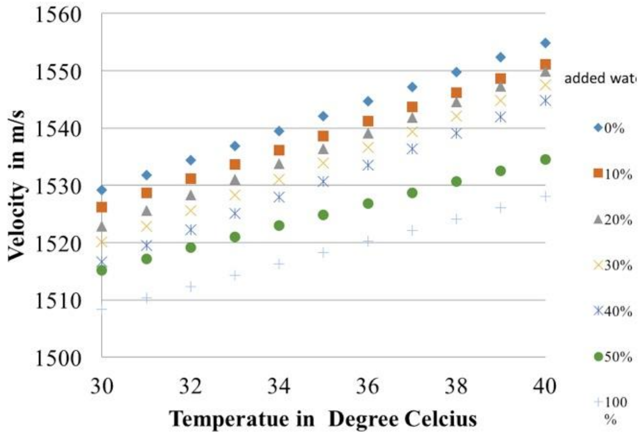

Figure 7. Effect of added of water on the ultrasonic velocity of milk.

4.2 Pure milk with water and sugar as adulterant

The pure milk is mixed with water and sugar added to compensate for the density loss due to addition of water.10 samples are prepared with different concentration of sugar (.25g/10ml to 2.5g/10ml with .25 g/10ml increments) with pure milk. This result is shown in the figure 8 at 0% water added to milk.

Then water is mixed with milk different concentration levels. Five sets of samples are prepared with 10%, 20%, 30%, 40% and 50% of water added to milk. Each sample set is added with sugar at different concentration (.25g/10ml to 2.5g/10ml with .25 g/10ml increments). This result is shown in figure 8 at 10%, 20%, 30%, 40% and 50% water added with milk and sugar at different concentrations.

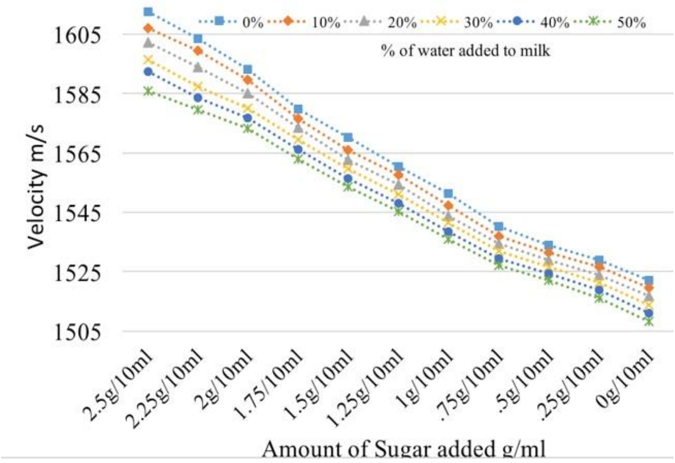

Figure 8. Effect of milk added with different amount of sugar and water on ultrasonic velocity.

Effect of milk added with different amount of sugar and water on ultrasonic velocity for 60 samples is measured. It shows an upward shift in velocity with increase in concentration of sugar and velocity decreases with the amount of water added with milk Figure 8 The temperature is kept constant for all measurements at 25 degrees Celsius. Acoustic impedance is calculated as the product of ultrasonic velocity and density measured using mass by the volume method. Due to fouling layer formation of milk in the measurement cell attenuation and reflection coefficient measurement is not reliable. Acoustic impedance is calculated as shown in figure 9.

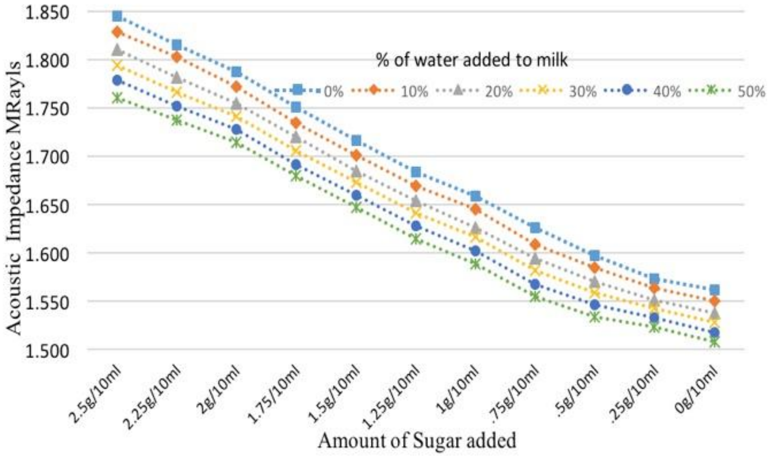

Figure 9. Acoustic impedance calculated as product of velocity and density for milk with sugar and water.

4.3 Pure milk with water and urea as adult-erant

The above experiment is repeated with urea as adulterant in milk and the following results are obtained as shown in Figure 10 Effect of milk added with urea and water on the ultrasonic velocity for 60 samples is measured. It shows an upward shift in velocity with increase in concentration of urea and velocity decreases with the amount of water added with milk. Acoustic impedance is calculated as shown in figure 11.

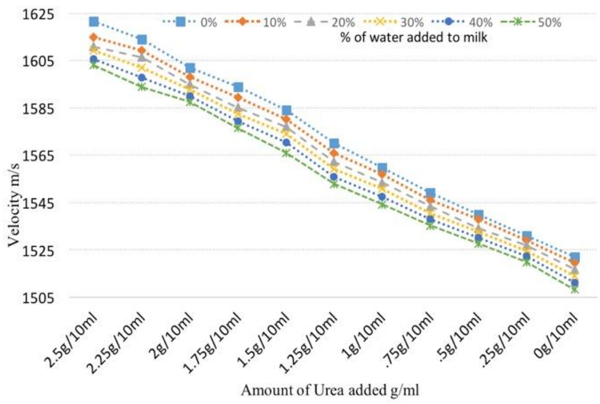

Figure 10. Effect of added Urea and water on the ultrasonic velocity of milk.

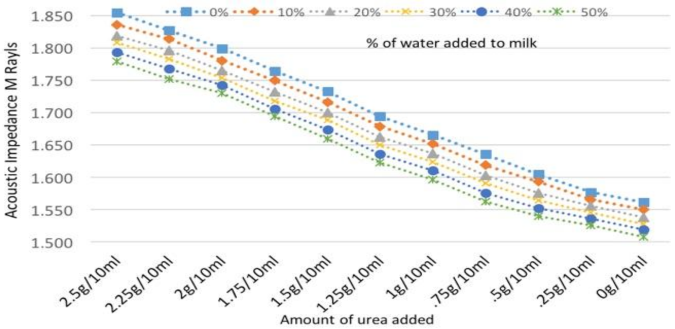

Figure 11. Acoustic impedance calculated as product of velocity and density for milk with urea and water.

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4.4 Comparison of Sugar and urea as Adulterant.

Figure 12 shows the effect of urea and sugar in milk adulterant with water. It is found that the milk added with urea has more velocity than the one with sugar. Also acoustic impedance value for urea added sample is high compared to the one with sugar and same density Figure 13

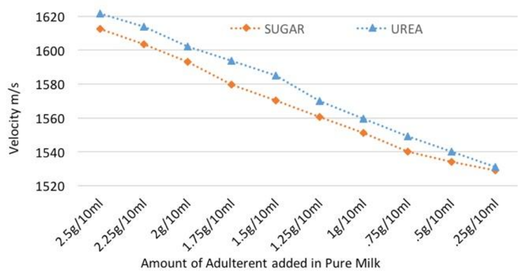

Figure 12. Comparison of Velocity of pure milk added with sugar and urea.

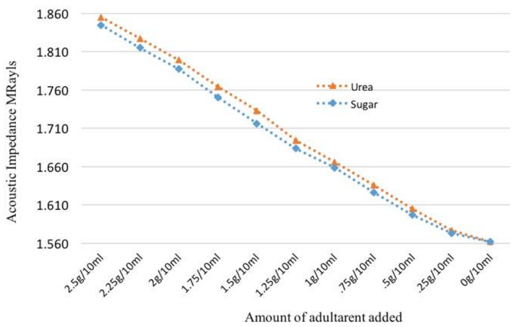

Figure 13. Acoustic Impedance of pure milk added with sugar and urea.

Comparison of density values, velocity values and acoustic impedance are shown in Table 1.

Table 1. Comparison of density, velocity and acoustic impedance of adulterated milk and pure milk

% of Water in MILK	Density Kg/m3	Velocity m/s	Acoustic Impedance M Rayls
0%	1026	1522	1.562
10% water	1020	1520	1.55
10% water +.25g/10ml Sugar	1024	1527	1.563
10% water +.25g/10ml Urea	1024	1529	1.566

5. CONCLUSION

The physical properties changes are linked to changes in ultrasonic parameters, which show that ultrasound can be used to assess and monitor milk quality and chemical additives. The feasibility, of using ultrasonic techniques to rapidly evaluate quality parameters for milk was investigated. Ultrasonic velocity for pure milk, milk + 10% water + .25g/10ml of sugar and milk + 10% water + .25g/10ml of urea are 1522 m/s**,** 1527 m/s and 1529 m/s, respectively. Chemical adulterants like urea and sugar is detected using this method. This method can be used for online monitoring of milk in the dairy industry to avoid adulteration of milk.

8. REFERENCES

[1] J. R. Allegra and S. A. Hawley, "Attenuation of sound in suspensions and emulsions: theory and experiments," J. Acoust*.* *Soc. Am.*, vol. ***51,*** *no.* 5, pp. 1545-1564, 1972.

[2] A.S **.**Ahuja, "Effect of particle velocity on propagation of sound in suspensions and emulsions," J. Acoust**.**Soc. *Am.*, vol. 51, no.I , pp. 182-191, 1972

[3] N. Bilaniuk and G. S. K. Wong, "Speed of sound in pure water as function of temperature", J. Acoust. Soc. Am., 93(3), 16091612.(1993).

[4] D. J. McClements, "Advances in the application of ultrasound in food analysis and processing," Trends in Food Sci. Technol., vol. 6 (9), pp. 239-299, 1995.

[5] S Mohanan , P G Thomas Panicker, Lilly Iype, M Laila, I Domini and R G bindu "A new ultrasonic method to detect chemical additives in branded milk" Vol. 59, No. 3 September 2002 pp. 525–529.

[6] I**.** C. Adamowski, E Buiochi, C. Simon, E. C. N. Silva, and R. A. Sigelmann, "Ultrasonic measurement of density of liquids," J. Acoust. Soc. *Am.*, vol. 97, no.I, pp. 354-361, 1995.

[7] Higuti, R.T.; Espinosa, M.F.R; and Adamowski, J.C. (2020). Energy method to calculate the density of liquids using ultrasonic reflection techniques, *Proc. IEEE Ultrasonic Symposium,* Atlanta GA, USA., 319– 322.

[8] Higuti, R.T.; and Adamowski, J.C. (2002). Ultrasonic densitometer using a multiple reflection technique, *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency control.*, 49, 1260–1268.

[9] Bjørndal, E.; Frøysa, K. E.; and Engeseth, S. A. (2008). A novel approach to acoustic liquid density measurements using a buffer rod based measuring cell, *IEEE Trans UFFC*, 55, 1794–1808.

[10] Nazário, S.L.S.; Kitano, C.; Higuti, R.T.; Isepon, J.S. and Buiochi, F. (2007). Use of ultrasound and neural networks to detect adulteration in milk samples, *Proceedings of the International Congress on Ultrasonics, Vienna*,1-4.

[11] Tony George, Elizabeth Rufus, Zachariah C Alex, "Quality Analysis of Transformer Oil in Hermitically Sealed Tank using Ultrasonic Lamb Wave Sensor" Indian Journal Of Science And Technology, Vol 9(20), May 2019.