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Study of Thermodynamic Properties of Comestible Oils Using Multi-Frequency Ultrasonic Device

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Abstract
Western India is the most prosperous region of India having the highest per capita consumption of Comestible oil. There are serious concerns that over-consumption and certain production processes of vegetable oil may lead to health problems, including inflammation and heart disease. In present paper, the variation of density with non-refined oils samples are selected. In the present study thermodynamic properties is such as Density (ρ), velocities (V), impedance (Z), Bulk modulus (K) and Compressibility (β) of Comestible oil are investigated at various frequencies at constant temperature using multi-frequency ultra-sonic device.

Keywords: *Acoustic; Bulk modulus; Comestible; Impedance; Ultrasonic Velocity.*

1. Introduction
Comestible vegetable oils form a vital part of the modern diet. Tin addition to providing the diet with numerous advantageous micronutrients, these oils serve as a source of energy. Global vegetable oil production amounted to around 209.14 million metric tons in 2020/21 Fats and oils are constructed of building blocks called “triglycerides” resulting from the combination of one unit of glycerol and three units of fatty acids. Western India is the most prosperous region of India having the highest per capita consumption of Comestible oil. The acceptability of Palm oil has improved and it has nearly 35% share. But even with a 35% share, this region is the second-highest consumer of Palm oil on account of high per capita consumption. MP and Maharashtra are the highest Soy oil-consuming region as the major domestic Soybean crop is grown and there is a good household demand. The Mustard oil consumption is 9% which is majorly in Rajasthan. Gujarat has switched to cottonseed oil from conventionally groundnut oil. North India was conventionally a Mustard oil & Groundnut oil market but, has somewhat shifted to Soy oil for household Consumption and palm oil for out-of-home eating. This market is a perfect mix sack of all oils. It has the lowest stake in percentage terms of Palm oil as it is the colder region of India the highest customer of Palm oil both in total and percentage terms. Furthermore, it represents India's largest market for sunflower oil. There is a small stake of soya oil and very low other oil consumption. East India is the lowest per capita consuming region due to lower income levels. This has a 40 % share of Palm Oil, but this is the second region after the south where largely the whole of the region has accepted Palm oil in the domiciliary. East India is the major market of Mustard oil (29% share). In this research work the study of thermodynamically properties of Comestible oil using multi-frequency ultrasonic interferometers, such as Density (ρ), ultrasonic velocities (V), Acoustic impedance (Z), Bulk modulus (K), and Compressibility (β). The Ultrasonic velocity has been measured for some Comestible oils specifically soybean oil, linseed oil, and mustard oil at three different frequencies 1MHz, 2MHz, and 3MHz, constant temperature. Ultrasonic velocities measured

by using an ultrasonic interferometer and density measurements have been carried out by a specific gravity bottle respectively. Various acoustic parameters, as mentioned above, are estimated using the data of ultrasonic velocity and density. The results found are critically discussed as a function of frequencies [1]. A new type of multi-frequency ultrasonic interferometer is used to measure the velocity of sound in liquids precisely through a systematic study of the thermodynamic properties of the solutions. The path length in the cell is varied by the motion of a reflector. The electrical reaction of the cell upon the oscillator is used to fix the standing wave position at a standard frequency, and their locations are determined with a micrometer attached to the reflector.

2. Review of Literature

(E. Rekha et al.,2020) In this paper the variation of density with temperature ranges from 303 to 333K for the oils selected in the present study, are not perfectly linear. Ultrasonic Velocities at a frequency of 3MHz have also been measured in the temperature range 303 to 333. It is observed that the Ultrasonic Velocities decrease approximately linearly. Velocity changes with temperature are attributed to change in intermolecular distance in oils [1].

(El-Hamidi, Mona, et al. 2018) In this study, two global crises—food and energy—are examined. Lately, there have been significant global efforts made to boost the production of oilseed crops, increase the oil content of the oilseed, and improve the quality of the oil that can be extracted from the seed to be more suitable for use either Comestible or non-Comestible purposes. Genetic engineering and agricultural breeding have been used in these endeavors [2].

(Satheesh Kumar V et al., 2016) This study's findings on the thermal conductivity of liquids utilized in heat transfer likely to be more accurate because thermal conductivity increases with temperature. applications which are easily susceptible to variable temperature. The ultrasonic technique involving only 2% error in thermal conductivity calculation for water and the consideration of one thermophysical property as a function of all other thermophysical property enables to provide more reliable and accurate results [3].

(Indu Saxena et al., 2015) the measurement of density, ultrasonic velocity, viscosity, and working principle of ultrasonic interferometer have been discussed in this paper. Furthermore, the current work provides a synopsis of the experimental design, constituent elements, the ultrasonic interferometer's operation, and several thermodynamic parameters have been evaluated using theoretical equations [4].

(R. Kameswari et al., 2014) in this research the variation of density with temperature for refined sunflower oil is not perfectly linear. The densities of sunflower oil calculated from modified rackett equation theoretically are showing only 2% error. So, it can be used to calculate densities theoretically. The thermal expansion of oil is more between the temperatures 300c to 450c. Molar volume changes with temperature indicate that there is loose packing of molecules at higher temperatures (above 50c) [5].

(Mahammad Ali, SK, et al. 2014) In this study, the ultrasonic velocity of six basic (unrefined) versions of certain regularly used edible oils is evaluated at different frequencies using a multi-frequency Ultrasonic Interferometer. Density and Ultrasonic velocity (V) and Density (ρ), Acoustic impedance (Z) was computed [6].

(Rubalya Valantina.et al., 2013) in this research Comestible oils are characterized in terms of their fatty acids and their flow behavior. The result shows that the oils with more double bonds appeared to have lower viscosity due to their loosely packed structure and the oil exhibit Newtonian behavior. Also, their flow behaviors with temperature could be well characterized by the Arrhenius model, Vogel Fulcher-Tammann, and Andrade's equations [7].

(T. Sankarappa et al.,2005) In this research Ultrasonic velocity at a frequency of 3 MHz and density measurements in the tempera- true range 298–333 K have been carried out in refined and unrefined Coconut oil(refined)s, castor oils, sunflower oils, groundnut oil and Kardi (safflower) oil, which are predominantly used as Comestible oils in south India. Saponification values of the oils are determined through a chemical volumetric titration method. It has been observed. That the velocity decreases approximately linearly with temperature in refined and unrefined sunflower oils and refined groundnut oil, and nonlinearly in refined and unrefined Coconut oil, castor oils, and unrefined Kardi (safflower) oil [8].

3. Materials and Methods

In the present study, is use three samples of commonly used unrefined Comestible oils were selected, is soybean oil, linseed oil, and mustard oil. In the market, these oils are easily accessible. These oils are extracted from seeds and fruits.

Soybean oil seeds: The scientific name of this oil is Glycine max. The linoleic fatty acid is the major fatty acid in soybean oil which ranges between 38 and 60%, followed by oleic in the range of 20–50%. About 1.45% of soybean oil is unsaponifiable matter, which is made up of 26% hydrocarbons, 8.5% tocopherols, and 16% sterols. These insignificant components of soybean oil are useful goods for commerce. They include lecithin, phytosterols, and tocopherols. Food emulsifiers primarily come from lecithin, which is made by degumming soybeans. It should be emphasized that soybean oil is also associated with several uses in industries as it is used in pharmaceuticals production, productions of plastics, papers, inks, paints, varnishes, cosmetics, and pesticides.

Linseed/flaxseed oil: Linseed (Linum usitatissimum L.) belongs to the Linaceae family. The oil content of linseed ranges between 28 and 30%. The major fatty acid of linseed oil is linolenic acid (53.21%) followed by oleic acid (18.51%), linoleic acid (17.25%), and palmitic and stearic acids (6.58 and 4.43%, respectively). Sterols are present at 4072 mg/kg in flaxseed lipids and the main sterols are β-sitosterol being 34.6%, of the total amounts of sterols in flaxseed lipids. Flaxseed lipids have a tocopherol content of 747 mg/kg, with 72.7% of the total amount being γ-tocopherol, which is the predominant kind. Linseed oil is widely utilized in numerous industrial applications, such as drying oils, and in a wide range of pharmaceutical goods. Because linseed oil contains omega-3-α-linolenic acid, it can be used as an additional dietary component. Owing to the presence of highly unsaturated fatty acids, it is not recommended for use in cooking. Therefore, more work is required to create new types of cooking oil that have low linolenic acid levels so that it can be extensively used.

Mustard Oil: The scientific name of this oil is Brassica Juncea. In India, about 67% of the population consumes, three Comestible oils mustard oil, palm oil, and soybean oil in north, north-east, and east regions, out of which mustard oil is locally accepted as its pungency adds to the taste. After palm and soybean, mustard is the major oilseed crop in the world. In the production of Comestible oil, it contributes 12% at the world level and 80 % in the country. Rajasthan is the leading state in India leading in the area and production of mustard which contributes more than 50%. Other mustard growing states are Haryana, Uttar Pradesh, Madhya Pradesh, and Gujarat. There are two common types of mustard oils are available in the market as traditional oil expellers and chemically processed oil expellers, which are mainly used for cooking purposes in India. With consideration of its health advantages as a major source of Mono Unsaturated Fatty Acid (MUFA).

4. Methodology

A multi-frequency ultrasonic interferometer is a simple and direct device that yields accurate and consistent data, from which one can determine the velocity of ultrasonic sound in a liquid medium with a high degree of accuracy. A crystal-controlled interferometer (model M-81S) supplied by Mittal Enterprises, New Delhi, operating frequencies ranging from 1 to 4 MHz has been used to measure the ultrasonic velocity. A straightforward tool for accurately determining the ultrasonic velocity in a liquid is an ultrasonic interferometer. Piezoelectric techniques are used in an ultrasonic interferometer to generate ultrasonic waves. Sound in an experimental liquid medium is measured at a fixed frequency variable path interferometer, allowing one to compute the sound's velocity across the medium. The 10 ml capacity, double-walled brass cell with chromium-plated surfaces makes up the ultrasonic cell. The experimental liquid is kept at a known constant temperature by water circulation around it, which is made possible by the double wall. The micrometer scale is marked in units of 0.01 mm and has an overall length of 25 mm. Fixed at the bottom

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of the cell is a quartz crystal that generates ultrasonic waves with a known frequency. Parallel to the quartz plate is a moveable metallic plate that reflects the waves. The waves interfere with their reflections, and if the separation between the plates is exactly an integer multiple of half wavelength of sound, standing waves are produced in the liquid medium. Under these circumstances, acoustic resonance occurs. A corresponding maximum in the anode current of the piezoelectric generator is caused by the resonant waves' maximum amplitude. A multi-frequency ultrasonic interferometer has following significant advantages such as:

- It is simple in design, rugged, and gives very accurate and reproducible results.
- Experiments may be performed over a wide range of temperature from -30 0C to +80 0C on all liquids except those which reacts with the plating of cell and crystal.
- Nearly 10 ml of experimental liquid is required.
- There is no danger of any change such as depolymerization, due to the ultrasonic effect since a very small ultrasonic energy is required [4].

The purpose of the high-frequency generator is to create ultrasonic waves in the experimental liquid by stimulating the quartz crystal that is fixed at the bottom of the measuring cell at its resonant frequency. filled in the "measuring cell". On the panel of the high-frequency generator is a micrometer to monitor changes in the two current controls for sensitivity regulation and micrometer initialization. The liquid's temperature will be kept constant during the experiment thanks to the particular construction of the measuring cell. The top of the device features a tiny digital micrometer screw (LC 0.001 mm) that allows you to raise or lower the reflector plate in the cell's liquid by a known distance. It has a quartz crystal fixed at its bottom. Figure 1 & 2 shows the multi-frequency ultrasonic device setup and experimental arrangement for multi-frequency ultrasonic device.

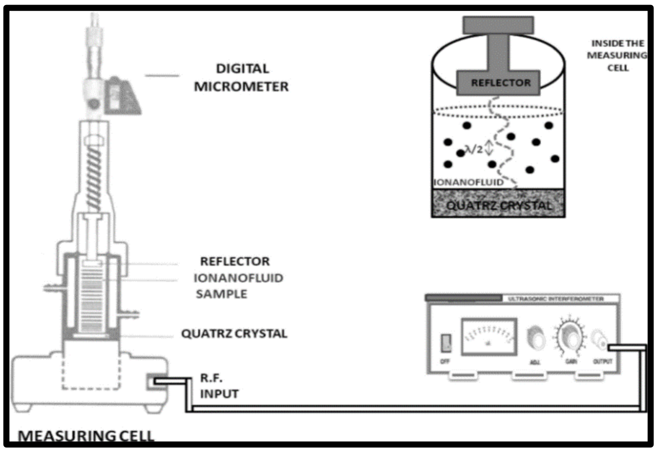

Figure 1 Multi-Frequency Ultrasonic Device Setup

Figure 2 Experimental Arrangement for Multi-Frequency Ultrasonic Device

4.1. Measurement of the Density (P)

The density measurements were made by density bottle. It was placed in a for temperature control. The density bottle was calibrated initially using distilled water. The densities measured for distilled water were found to be 0.93648 and 0.9399 g/cc respectively at 298.15K. Thus, the measured values were in good agreement with their literature values.

$$Density(\rho) = \frac{mass}{volume} \qquad (1)$$

4.2. Ultrasonic Velocity (V)

The principle used in the measurement of velocity (V) is based on the accurate determination of the wavelength (λ) in the medium. A quartz crystal that is fixed at the bottom of the cell produces ultrasonic waves with a defined frequency (v). A metallic plate

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that can be moved and is positioned parallel to the quartz crystal reflects these waves. Standing waves arise in the medium if the distance between these two plates is precisely a whole multiple of the wavelength of sound. This acoustic resonance gives rise to an electrical reaction on the generator driving the quartz crystal and the anode current of the generator becomes a minimum. In the event that the distance is altered and the variation is precisely half a wavelength (λ /2) or greater, the anode current will decrease due to the understanding that wavelength (λ) the velocity (V) can be obtained by the relation:

$$velocity(V) = Wavelength\,(\lambda) \times \text{Frequency}(\nu) \quad (2)$$

4.3. Acoustic Impedance (Z)

Sound pressure affects how sound moves through various materials. Waves propagate through solids due to the elastic bonding between molecules or atoms. This phenomenon is caused by excess pressure. The acoustic impedance (Z) of a material is defined as the products of its density (ρ) and ultrasonic velocity (V) given as.

$$Z = \rho \times V \quad (3)$$

Where

ρ is the density
V is the velocity

4.4. Bulk Modulus (K)

A unit compressive or tensile stress applied uniformly across a body's surface causes a relative change in volume. Products of its density (ρ) and ultrasonic velocity square.

$$K = \rho \times V^2 \quad (4)$$

Where,

ρ is the density.
V is the velocity.

4.5. Compressibility (B)

The relative volume change of a liquid under varying pressure is known as its compressibility. Fluid mechanics and thermodynamics are related to compressibility. It is denoted by beta “β". The Compressibility of a fluid depends on the adiabatic or isothermal process. It can be represented in the formula below.

$$\beta = \frac{1}{K} \quad (5)$$

5. Result and Discussion

The Thermodynamic Properties of Comestible oil using multi-frequency ultrasonic interferometer, the values of density of some Comestible oils at constant temperature (303K) as shown in Table 1, It is observed that it is valued slightly change is minimum that to be found than other oils mustard and maximum in linseed oil.

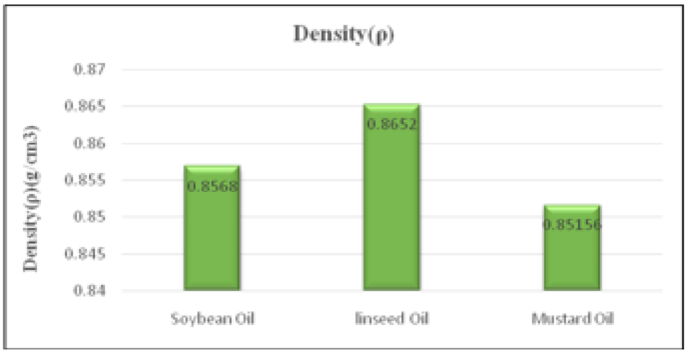

Figure 3 **Density Variation as a Function of Temperature of Selected Comestible Oils**

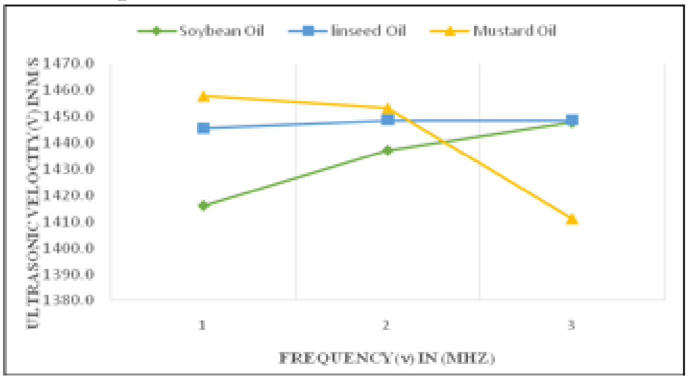

Figure 4 **Ultrasonic Velocity Variation as a Function of Frequency of Selected Comestible Oils**

From Figure 3&4 it is found that the values of the ultrasonic velocity of various Comestible oils at 1, 2, and 3 MHz frequencies. It is found there is a marked difference in ultrasonic velocity in all Comestible oils studied at 1MHz frequency the variation of ultrasonic velocity range from 1416.00m/s to in soybean oil to 1457.7142 m/s in measure oil A significant increase in velocity is found as we proceed from soybean to mustard oil. To an extend of 41.7142 m/s at 1MHz frequency. At 2MHz frequency, the ultrasonic velocity was found that there is increase two oils linseed and soybean oils and one oil shows decrees mustard oil, as compared to 1MHz & 2MHz. the

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ultrasonic velocity studies at 3MHz frequency show an increase in soybean oil values greater than other oils this is because soybean oil is more viscous than other oils.

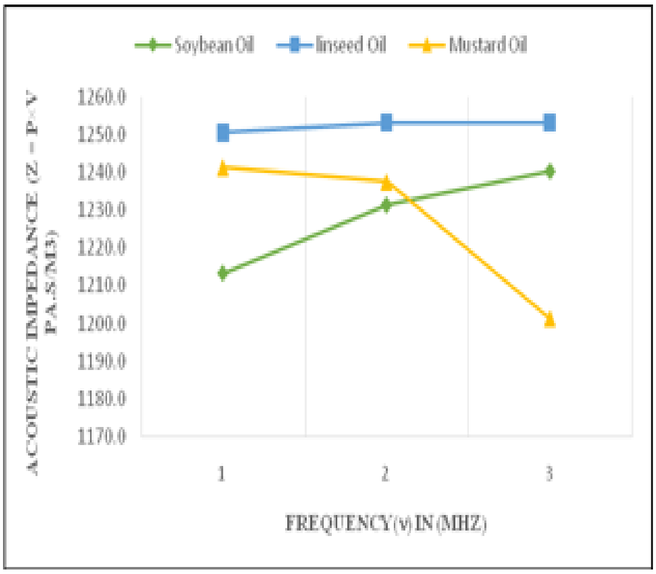

Figure 5 Acoustic Impedance Variation as a Function of Frequency of Selected Comestible Oils

From Figure 5 it is found that the acoustic impedance, shows variation at 1MHz frequency ranging from 1213.2288Pa. S/m^3 for soybean oil to 1250.58 Pa. S/m^3 linseed oil. the significant increase in acoustic impedance from soybean oil to linseed oil to an extend of 37.3512Pa. S/m^3 at 1MHz frequency. At 2MHz frequency, acoustic impedance increases in two oils namely soybean and linseed oils, and only one oil shows a decrease in mustard oil. At 3MHz frequency, acoustic impedance increases in soybean and linseed oil whereas mustard oil show decrement. From Figure 6 it is found that the bulk modulus, shows variation at 1MHz frequency range from 17179.3×10^5 N/m^2 in soybean oil to 18076.3099734×10^5 N/m^2 linseed oil the significant increases in bulk modulus is found as we proceed soybean oil to linseed oil to an extend of 897.0×10^4 N/m^2. At 2 MHz frequency, the bulk modulus increases in soybean and linseed oils whereas remaining only one it decreases. At 3MHz frequency, the value of bulk modulus is stable in linseed oil while it is decreasing in other oils.

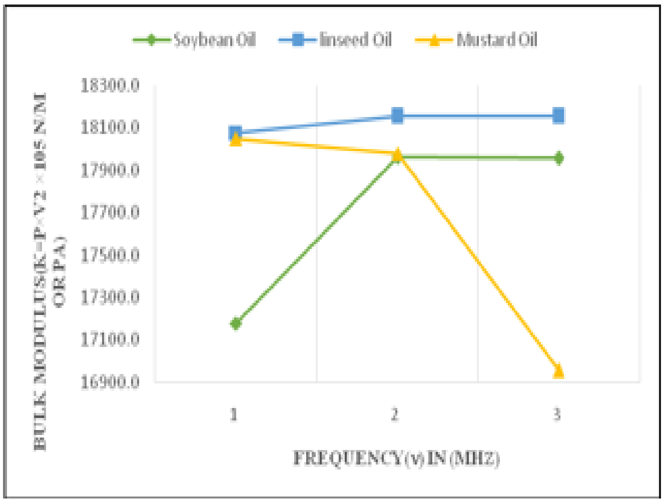

Figure 6 Bulk Modulus Variation as a Function of Frequency of Selected Comestible Oils

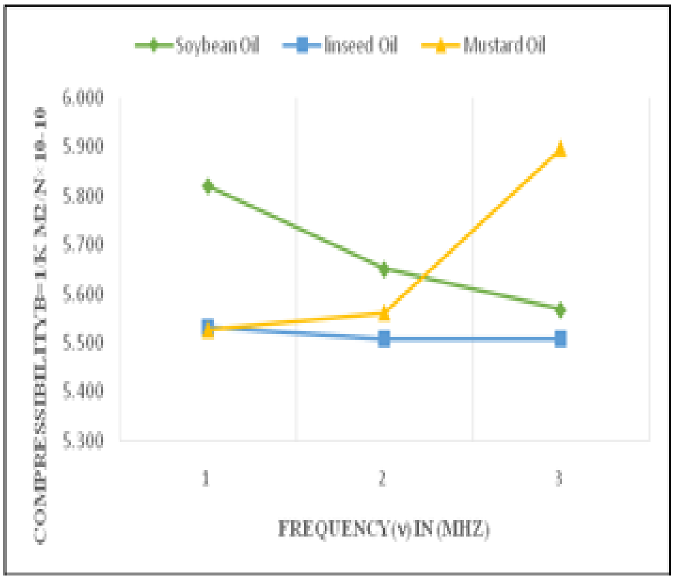

Figure 7 Compressibility Variation as a Function of Frequency of Selected Comestible Oils

From Figure 7 it is found that the compressibility, shows variation at 1MHz frequency range found 5.52×10^{-10} m^2/N in mustard oil to 5.82×10^{-10} m^2/N soybean oil, the significant increases incompressibility is found as we proceed mustard oil to soybean oil to an extend of 0.3×10^{-10} m^2/N. At 2MHz frequency, compressibility increases in mustard oils whereas another two samples show decrement. At 3MHz frequency, the compressibility increases in whereas other oils show decrement. The compressibility is inversely proportional to ultrasonic velocity, acoustic impedance, and bulk modulus.

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Table 1 Densities, Ultrasonic Velocities and Acoustic Parameters of Comestible Oils

Sr. No.	Sample	Temperature(K)	Density(g/cm^3)	Frequency in (Hz)	Ultrasonic Velocity(m/s)	Acoustic impedance (Z = ρ×V Pa.s/m^3)	Bulk modulus (K=ρ×V^2 N/m^2 or Pa)	Compressibility B=1/K m^2/N×10^{-10}
1	Soybean Oil	303	0.8568	1×10^6	1416.00000	1213.2288	17179.3	5.8209523518400
				2×10^6	1437.14286	1231.4340	17961.7	5.6509395175900
				3×10^6	1447.71429	1240.4016	17957.5	5.5687127935700
2	linseed Oil	303	0.8652	1×10^6	1444.42857	1250.5848	18076.3	5.5321025224200
				2×10^6	1448.57143	1253.3040	18154.0	5.5081233631900
				3×10^6	1448.57143	1253.3040	18154.0	5.5081233631900
4	Mustard Oil	303	0.85156	1×10^6	1457.71429	1241.3312	18050.6	5.5263695671400
				2×10^6	1453.14286	1237.4383	17981.7	5.5611949794900
				3×10^6	1411.14286	1201.3628	16957.3	5.8971582379400

Conclusion

This work reveals that the ultrasonic velocity depends on the percentage of unsaturated fatty acid and saturated fatty acid in Comestible oils. Some oils are increase and some oils are decreasing in the present study found to be values of acoustic impedance are less in Coconut oil (refined). The bulk modulus is ultrasonic velocity, acoustic impedance, and compressibility. In the compressibility found of the experimental data in coconut increase and other oils are stable values the compressibility inversely proportional to the other parameters. This study is concluding that the density with constant temperature (303 K) of deferent oils sample shows the variation in acoustic parameters. The ultrasonic velocity is in agreement with the result reported by E. Rekha and R. Jeevan Kumar, the variation of ultrasonic velocity with frequency is not perfectly linear. Acoustic impedance (Z), Bulk modulus (K), and Compressibility (β) are estimated using the data of ultrasonic velocity and density. Acoustic impedance (Z), Bulk modulus (K) is decreasing with an increase in temperature. The compressibility (β) of oils is increasing with temperature. All these variations may be due to breakages of weak polar bonds between the polar ends of triglyceride molecules. Acoustic impedance is less in Coconut oil and is more in the case of Linseed oil with in-between values for Groundnut, Soybean, Sesame, and Mustard oils. These acoustic impedance values, along with any variations found in the oils systems under investigation, can be used as benchmarks for calibration and cross-checking. oils are adulterated

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