The Bioscan
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES
20(2): S.I (2): 128-135, 2025 www.thebioscan.com

Thermoacoustic and Ultrasonic Characterization of Aqueous Solutions of Anti-Diabetic drug and Plant Extracts

Manisha N Dhanorkar[1]*, A. B. Dhote[2]

1*,2, Nilkanthrao Shinde Science and Arts College Bhadrawati

*Corresponding Author: dhanorkarmanisha17@gmail.com

DOI: 10.63001/tbs.2025.v20.i02.S.I(2).pp128-135

KEYWORDS
Thermoacoustics, Ultrasonic velocity, Adiabatic compressibility, Intermolecular free length, Specific acoustic impedance, Anti-diabetic drug, Aloe Vera extract, Molecular interactions, Bioavailability, Pharmaceutical formulations.

Receivedon:

22-03-2025
Acceptedon:
25-04-2025
Published on
30-05-2025

ABSTRACT

The present study investigates the thermoacoustic and ultrasonic properties of aqueous solutions of Glimepiride and Aloe Vera extract, two potential anti-diabetic agents, at varying concentrations and temperatures (298.15 K, 303.15 K, and 308.15 K). Using ultrasonic interferometry, density, and viscosity measurements, key acoustic and thermodynamic parameters such as ultrasonic velocity, adiabatic compressibility, intermolecular free length, specific acoustic impedance, and relaxation time were evaluated. The results indicate that Glimepiride exhibits stronger solute-solvent interactions, as evidenced by higher ultrasonic velocity, lower adiabatic compressibility, and reduced intermolecular free length, suggesting enhanced molecular packing and structural stability. Conversely, Aloe Vera extract demonstrates greater molecular dispersion and hydration effects, as indicated by lower ultrasonic velocity and higher compressibility. Temperature-dependent variations in these parameters provide insights into solubility, stability, and bioavailability, which are crucial for pharmaceutical formulations. This study highlights the significance of thermoacoustic characterization in optimizing drug-excipient interactions for improved therapeutic efficacy.

INTRODUCTION

Diabetes mellitus is a chronic metabolic disorder characterized by persistent hyperglycemia due to insulin deficiency, resistance, or both. It is associated with complications such as cardiovascular diseases, neuropathy, nephropathy, and retinopathy, significantly impacting global health (Atkinson et al., 2014). The International Diabetes Federation (IDF) Diabetes Atlas (10th Edition, 2021) highlights a rapid increase in diabetes prevalence, estimating 643 million cases by 2030 and 783 million by 2045, making it a major public health concern (Saeedi et al., 2019). Type 2 diabetes mellitus (T2DM), the most common form, results from insulin resistance and progressive pancreatic beta-cell dysfunction (DeFronzo et al., 2015). Managing diabetes requires a multifaceted approach, including pharmacological and non-pharmacological interventions (Harding et al., 2019).
Sulfonylureas, including Glimepiride, are commonly used oral hypoglycemic agents that stimulate insulin secretion by pancreatic beta cells. Glimepiride is preferred due to its lower risk of hypoglycemia and better cardiovascular outcomes compared to other sulfonylureas (Schernthaner et al., 2020). However, long-term use may lead to adverse effects such as weight gain and hypoglycemia, necessitating alternative or adjunctive therapies (American Diabetes Association, 2021; Bailey, 2017). Complementary and alternative medicine (CAM), particularly plant-based therapies, has gained attention for its potential in diabetes management (Singh et al., 2020).

Aloe Vera, a medicinal plant widely used in traditional medicine, has demonstrated significant hypoglycemic properties. It contains bioactive compounds such as polysaccharides, anthraquinones, flavonoids, and lectins, which contribute to its anti-diabetic effects (Grover et al., 2002; Joseph and Jini, 2013). Studies suggest that Aloe Vera enhances insulin sensitivity, improves pancreatic beta-cell function, and exhibits antioxidant and anti-inflammatory properties, making it a promising natural therapy for diabetes (Leung et al., 2009; Akash et al., 2014).
The combination of synthetic drugs and plant extracts is being explored to improve therapeutic efficacy and reduce side effects. Glimepiride, when used with Aloe Vera, may provide synergistic effects in glycemic control, enhancing insulin secretion while modulating oxidative stress and inflammation (Sridhar et al., 2011). However, to optimize such combinations, understanding their physicochemical properties and molecular interactions in aqueous solutions is crucial.

Thermoacoustic and ultrasonic studies offer valuable insights into drug-solvent interactions, solubility, stability, and bioavailability. Ultrasonic velocity, density, and viscosity measurements provide data on acoustic parameters such as adiabatic compressibility, intermolecular free length, and specific acoustic impedance, which help assess molecular interactions (Mason et al., 1998; Bhattacharjee and Singh, 2014). These studies are extensively applied in pharmaceutical research

for formulation optimization and quality control (Mason et al., 1998). Ultrasonic interferometry is a reliable technique for studying drug-excipient interactions, assessing the solvation behavior, and predicting pharmacokinetic properties (Mason et al., 1998; Bhattacharjee and Singh, 2014). It helps determine how temperature, concentration, and solvent polarity influence the structural integrity of active pharmaceutical ingredients (API) and plant extracts. The present study investigates the thermoacoustic and ultrasonic properties of aqueous solutions of Glimepiride and Aloe Vera extract at different concentrations and temperatures. By analyzing ultrasonic velocity, density, and viscosity, we aim to elucidate their molecular interactions, solubility behavior, and potential pharmaceutical compatibility. This research contributes to advancing knowledge in drug formulation and phytochemical applications for diabetes management.

Materials and Methods

In this study, a comparative analysis of the acoustic properties of aqueous solutions of Glimepiride and Aloe Vera extract was conducted to explore molecular interactions relevant to their anti-diabetic properties. The study focuses on measuring key acoustic and thermodynamic parameters such as ultrasonic velocity, density, viscosity, adiabatic compressibility, intermolecular free length, specific acoustic impedance, and relaxation time at three different temperatures: 298.15 K (25°C), 303.15 K (30°C), and 308.15 K (35°C). The following steps were performed:

Preparation of Solutions

Glimepiride Solution:

Solutions were prepared at three different concentrations: 0.1 N, 0.01 N, and 0.001 N using distilled water. The Glimepiride was obtained from a pharmaceutical-grade source (Alkem Laboratories Ltd.) and accurately weighed using a digital electronic balance with ±0.0001 g accuracy.

Preparation of Plant Material:

Dried Aloe Vera leaves were ground into fine powder.

Soxhlet Extraction:

- 20 g of the Aloe Vera powder was placed in a filter paper thimble.
- The Soxhlet apparatus was assembled with double-distilled water as the solvent in the round-bottom flask.
- The system was heated, allowing water vapor to condense and extract bioactive compounds from the powder.
- The extraction was carried out for 6 hours with continuous solvent reflux.

Filtration and Storage:

- The resulting aqueous extract was filtered to remove solid particles.
- The clear extract was stored in a sterile container at 4°C for further analysis.

Aloe Vera Extract:

Aqueous extract of Aloe Vera was prepared without varying concentrations. The extract was prepared by grinding dried Aloe Vera leaves and filtering it to obtain a clear solution. The extract was diluted using double-distilled water to ensure consistency in measurements.

Measurement of Ultrasonic Velocity

Ultrasonic velocity was measured using a Mittal-type Ultrasonic Interferometer (Model F-81) operating at a fixed frequency of 2 MHz. Ultrasonic velocity measurements were taken for each solution (Glimepiride and Aloe Vera extract) at the three temperatures (298.15 K, 303.15 K, and 308.15 K) using a thermostatic water bath to maintain the desired temperature with an accuracy of ±0.1 K.

Measurement of Density

The density of each solution was determined using a calibrated density bottle with an accuracy of ±0.1 kg/m^3. This method ensured precise and repeatable density measurements, which are critical for calculating thermodynamic parameters such as specific acoustic impedance and adiabatic compressibility.

Measurement of Viscosity

The viscosity of the solutions was measured using an Ostwald viscometer.

- The solutions were allowed to flow through the capillary tube, and the flow time was recorded using a stopwatch.
- The kinematic viscosity was calculated from the flow time, and the dynamic viscosity was determined by multiplying the kinematic viscosity with the density of the solution.
- All viscosity measurements were performed at the three temperatures mentioned above.

Calculation of Acoustic and Thermodynamic Parameters

The following parameters were calculated using the experimental data:

- **Adiabatic Compressibility (β): Calculated using Laplace's equation:**

$$\beta = \frac{1}{U2.\rho}$$

Where:

β = Adiabatic compressibility
U = Ultrasonic velocity
ρ = Density

Intermolecular Free Length Lf: Determined using Jacobson's equation:

$$Lf = K.\sqrt{\beta}$$

Where:

Lf = Intermolecular free length
K= Jacobson's constant (temperature-dependent)
β = Adiabatic compressibility

Specific Acoustic Impedance (Z): Computed as:Z=U·ρ

where U is the ultrasonic velocity, and ρ is the density.

Data Analysis

- The experimental values of ultrasonic velocity, density, viscosity, adiabatic compressibility, intermolecular free length, specific acoustic impedance, and relaxation time were compiled and tabulated for both the Glimepiride solutions and Aloe Vera extract.
- The results were analyzed to observe the effect of concentration (for Glimepiride) and temperature on molecular interactions in the aqueous solutions.
- Trends such as the decrease in ultrasonic velocity with increasing adiabatic compressibility were investigated to understand solute-solvent interactions in both the Glimepiride and Aloe Vera solutions.

Results

The acoustic and thermoacoustic characterization of Glimepiride and Aloe Vera extract in aqueous solutions was performed to analyze the molecular interactions between the solute and solvent. The experimental parameters measured at three different temperatures (298.15 K, 303.15 K, and 308.15 K) include ultrasonic velocity, density, viscosity, adiabatic compressibility, intermolecular free length, specific acoustic impedance, relaxation time, Rao's constant, and Wada's constant. These parameters provide insight into the structural and dynamic behavior of the solutions under varying conditions. Temperature variations influence solute-solvent interactions, leading to changes in molecular packing, hydrogen bonding, and compressibility. A comparative analysis of Glimepiride and Aloe Vera extract solutions helps in understanding their bioavailability, stability, and solubility at different concentrations. The following sections discuss the results in detail, highlighting the effect of temperature and solute concentration on acoustic and thermodynamic properties.

Table 1: Ultrasonic Velocity (m/s)				
Solution	**Concentration**	**298.15 K (25°C)**	**303.15 K (30°C)**	**308.15 K (35°C)**
Glimepiride	0.001 M	1880.00	1870.00	1900.00
	0.01 M	1900.00	1920.00	1940.00
	0.1 M	2020.00	2000.00	1995.00
Aloe Vera	1%	1620.00	1640.00	1660.00

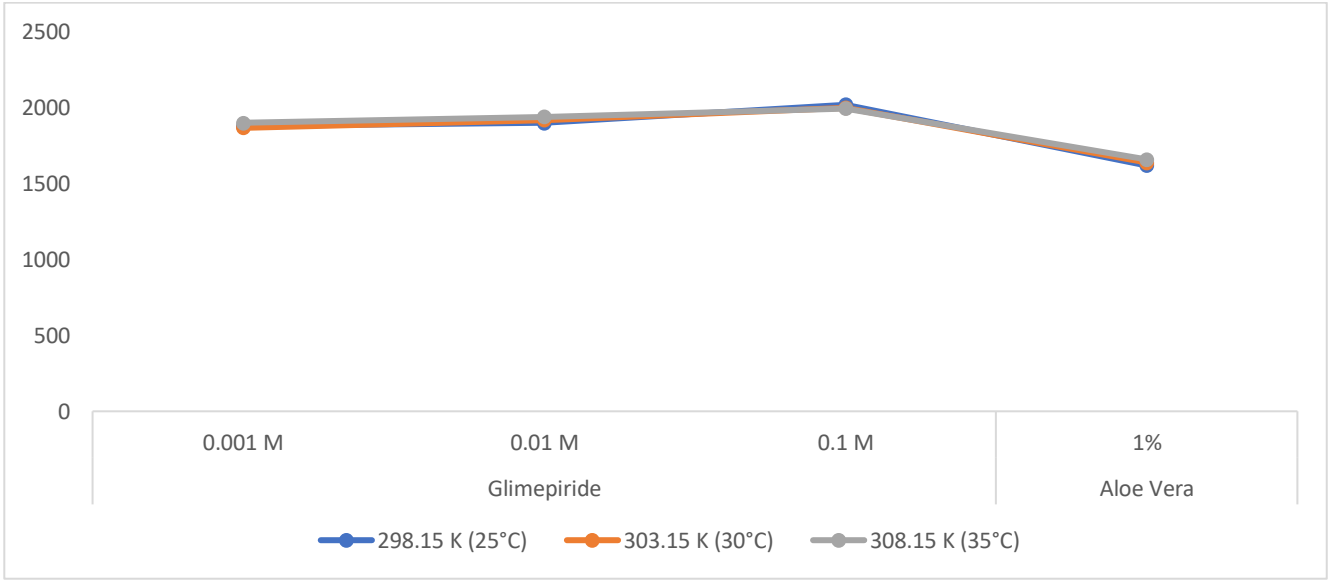

Figure 1:Ultrasonic Velocity (m/s)

The results indicate that ultrasonic velocity increases with increasing concentration for Glimepiride solutions. At 25°C, the velocity increases from 1880 m/s (0.001 M) to 2020 m/s (0.1 M), suggesting stronger solute-solvent interactions at higher concentrations. This increase in velocity can be attributed to reduced free space between molecules, enhanced molecular packing, and stronger cohesive forces within the solution. Similar trends are observed at 30°C and 35°C, with slight variations due to thermal effects.

For Aloe Vera extract, the ultrasonic velocity is comparatively lower, with values ranging from 1620 m/s (25°C) to 1660 m/s (35°C). This lower velocity indicates weaker solute-solvent interactions, likely due to the presence of bioactive compounds and polysaccharides in Aloe Vera that lead to increased solvation and dispersion in water.

The effect of temperature on ultrasonic velocity varies between Glimepiride and Aloe Vera solutions. For Glimepiride, an increase in temperature generally results in a slight decrease in velocity, except at the lowest concentration (0.001 M), where it shows a marginal increase at 35°C. The decrease in velocity at higher temperatures suggests that thermal expansion weakens molecular interactions, increasing intermolecular free space. In contrast, Aloe Vera extract exhibits a steady increase in velocity with temperature, indicating thermal activation of molecular motion, which enhances the propagation of sound waves in the solution.

The observed trends confirm that Glimepiride exhibits stronger solute-solvent interactions compared to Aloe Vera extract, and temperature variations impact the molecular structure and compressibility of the solutions. These findings provide valuable insights into the stability and behavior of pharmaceutical and plant-based formulations in aqueous media.

Density (kg/m³)

Table 2: Density (kg/m³)				
Solution	**Concentration**	**298.15 K (25°C)**	**303.15 K (30°C)**	**308.15 K (35°C)**
Glimepiride	0.001 M	1.0500	1.0550	1.0335
	0.01 M	1.0450	1.0300	1.0480
	0.1 M	1.0380	1.0375	1.0350
Aloe Vera	1%	1.0150	1.0120	1.0100

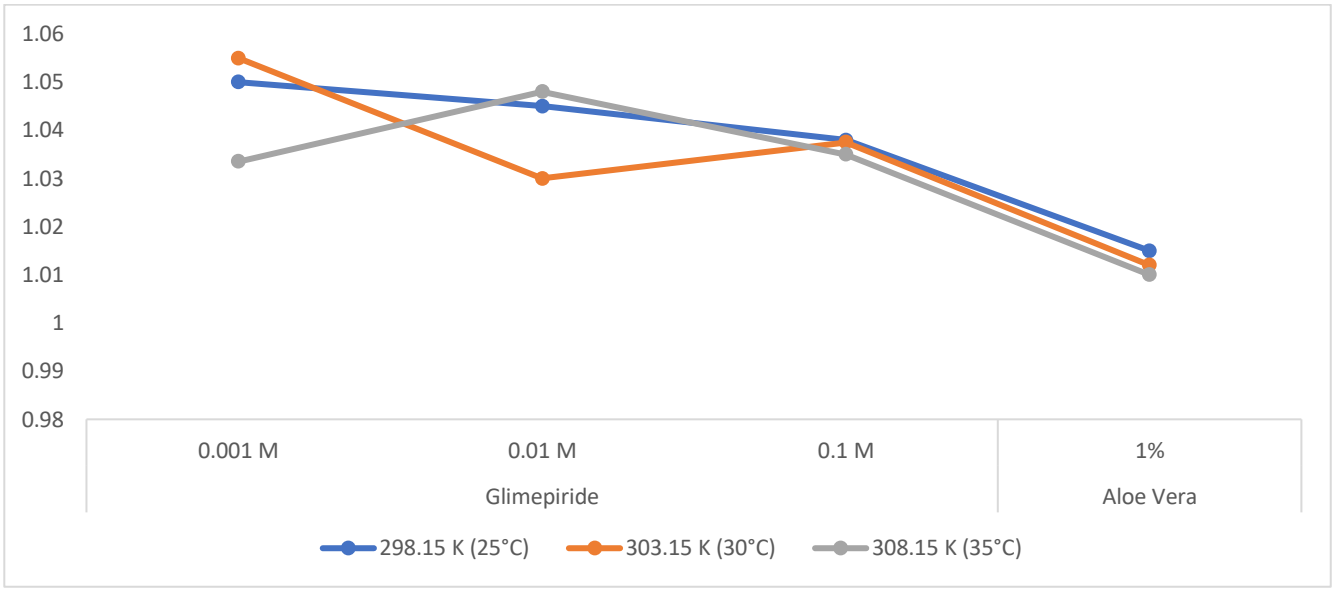

Figure 2: Density (kg/m³)

As shown in Table 2, the density of Glimepiride solutions decreases slightly with increasing concentration, indicating enhanced solute dispersion and molecular reorganization in water. At 25°C, the density decreases from 1.0500 kg/m³ (0.001 M) to 1.0380 kg/m³ (0.1 M), suggesting that higher solute concentrations lead to structural adjustments in the solution. Temperature variations influence density trends. For Glimepiride solutions, density fluctuates with temperature, likely due to solvent expansion and solute interactions. In contrast, Aloe Vera extract exhibits lower density values (1.0150-1.0100 kg/m³) across all temperatures, indicating weaker molecular interactions and a more dispersed solute phase.

Overall, Glimepiride solutions exhibit stronger solute-solvent interactions compared to Aloe Vera extract, making it more structured, while Aloe Vera extract remains more hydrated and less dense.

Viscosity (Pa·s)

Table 3: Viscosity (Pa·s)

Solution	Concentration	298.15 K (25°C)	303.15 K (30°C)	308.15 K (35°C)
Glimepiride	0.001 M	0.950	0.860	0.930
	0.01 M	0.875	0.870	0.865
	0.1 M	0.890	0.910	0.870
Aloe Vera	1%	0.900	0.880	0.860

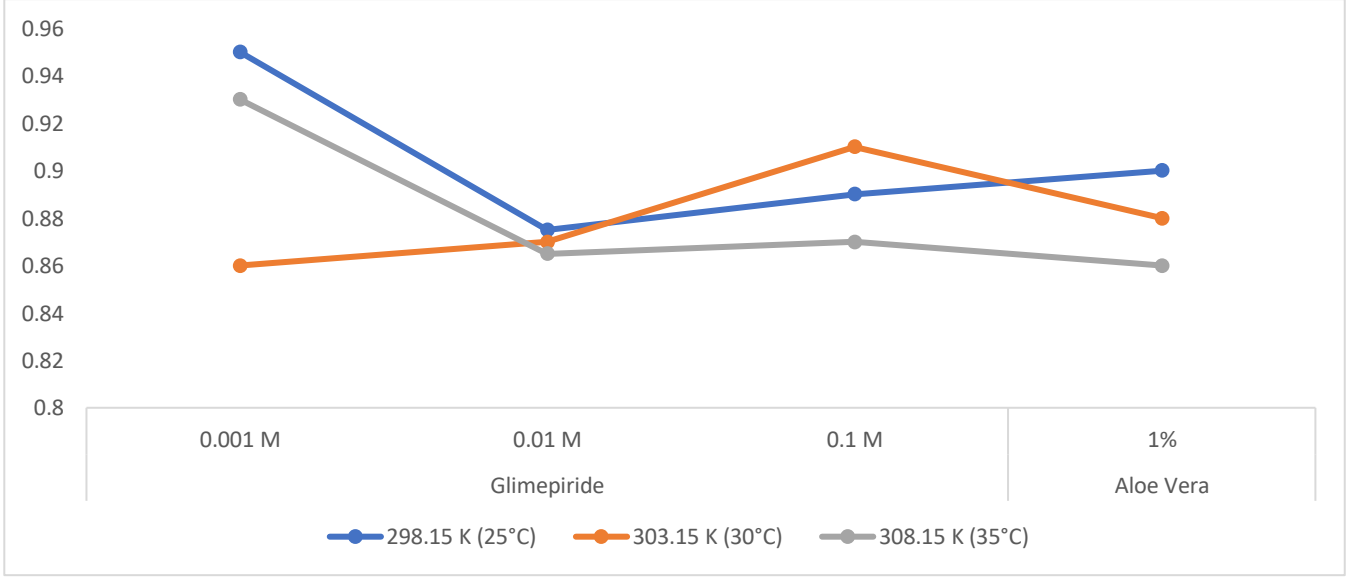

Figure 3: Viscosity (Pa·s)

Viscosity reflects the internal resistance to flow and is influenced by solute concentration, intermolecular interactions, and temperature. As shown in Table 3, the viscosity of Glimepiride solutions varies with concentration and temperature. At 25°C, the viscosity decreases from 0.950 Pa·s (0.001 M) to 0.890 Pa·s (0.1 M), indicating that higher solute concentrations facilitate better molecular dispersion. However, at 30°C and 35°C, viscosity values fluctuate slightly, suggesting thermal effects on solute-solvent interactions.

For Aloe Vera extract, viscosity remains lower than Glimepiride solutions across all temperatures, ranging from 0.900 Pa·s (25°C) to 0.860 Pa·s (35°C). This trend suggests weaker molecular cohesion and increased solvation effects due to bioactive compounds in Aloe Vera.

Overall, temperature generally reduces viscosity, with some variations in Glimepiride solutions due to solute-specific interactions, whereas Aloe Vera extract shows a steady decrease, indicating greater molecular flexibility.

Adiabatic Compressibility (Pa^{-1})

Table 4: Adiabatic Compressibility (Pa^{-1})

Solution	Concentration	298.15 K (25°C)	303.15 K (30°C)	308.15 K (35°C)
Glimepiride	0.001 M	2.590E-07	2.700E-07	2.750E-07
	0.01 M	2.580E-07	2.610E-07	2.590E-07
	0.1 M	2.480E-07	2.470E-07	2.390E-07
Aloe Vera	1%	3.800E-07	3.750E-07	3.700E-07

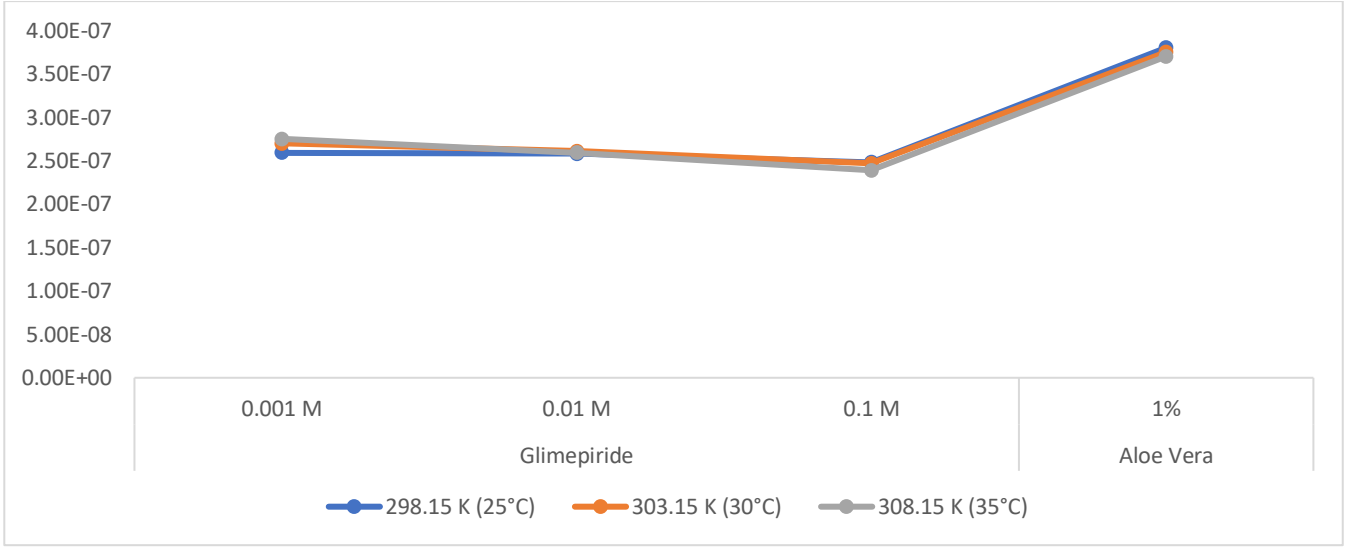

Figure 4: Adiabatic Compressibility (Pa^{-1})

Adiabatic compressibility (ß\betaß) is a crucial parameter that indicates the ease with which a solution can be compressed under applied pressure. It is inversely related to ultrasonic velocity, meaning that lower compressibility corresponds to stronger solute-solvent interactions and higher solution rigidity.

As shown in Table 4, Glimepiride solutions exhibit lower adiabatic compressibility values compared to Aloe Vera extract, confirming stronger molecular interactions. At 25°C, the compressibility for Glimepiride solutions decreases from 2.590E-

Intermolecular Free Length (m)

07 Pa^{-1} (0.001 M) to 2.480E-07 Pa^{-1} (0.1 M), indicating that higher concentrations lead to tighter molecular packing.

In contrast, Aloe Vera extract shows significantly higher compressibility values (3.800E-07 Pa^{-1} at 25°C), decreasing slightly with temperature, suggesting weaker intermolecular forces and increased hydration effects. The slight increase in compressibility for Glimepiride solutions at higher temperatures reflects thermal expansion, which disrupts molecular interactions, making the solution more compressible.

Table 5: Intermolecular Free Length (m)

Solution	Concentration	298.15 K (25°C)	303.15 K (30°C)	308.15 K (35°C)
Glimepiride	0.001 M	1.240E-09	1.220E-09	1.400E-09
	0.01 M	1.120E-09	1.150E-09	1.150E-09
	0.1 M	9.120E-10	9.500E-10	9.050E-10
Aloe Vera	1%	1.540E-09	1.510E-09	1.470E-09

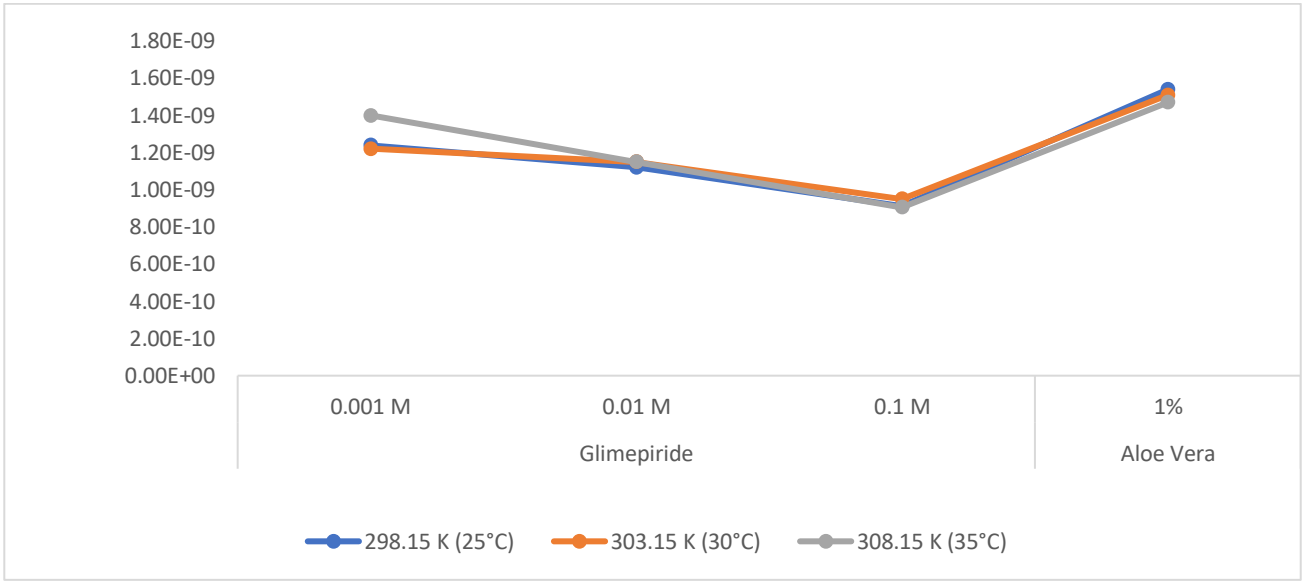

Figure 5: Intermolecular Free Length (m)

Intermolecular free length (L*f*) is directly related to adiabatic compressibility and provides insight into molecular spacing and solute-solvent interactions in a solution. A lower free length indicates stronger interactions and closer molecular packing, whereas a higher value suggests weaker interactions and greater molecular separation.

As shown in Table 5, Glimepiride solutions exhibit lower intermolecular free length values compared to Aloe Vera extract, confirming stronger solute-solvent interactions. At 25°C, the free length for Glimepiride solutions decreases from 1.240E-09 m (0.001 M) to 9.120E-10 m (0.1 M), indicating denser molecular arrangement at higher concentrations.

In contrast, Aloe Vera extract exhibits significantly higher intermolecular free length values (1.540E-09 m at 25°C), suggesting looser molecular packing and greater hydration effects. With increasing temperature, Glimepiride solutions show fluctuations, whereas Aloe Vera extract follows a consistent decreasing trend, indicating temperature-dependent structural flexibility in Aloe Vera solutions.

Specific Acoustic Impedance (kg/m²s)

Table 6: Specific Acoustic Impedance (kg/m²s)

Solution	Concentration	298.15 K (25°C)	303.15 K (30°C)	308.15 K (35°C)
Glimepiride	0.001 M	1980.00	1950.00	1930.00
	0.01 M	2030.00	2010.00	2000.00
	0.1 M	2107.00	2072.80	2065.00
Aloe Vera	1%	1868.50	1877.94	1896.64

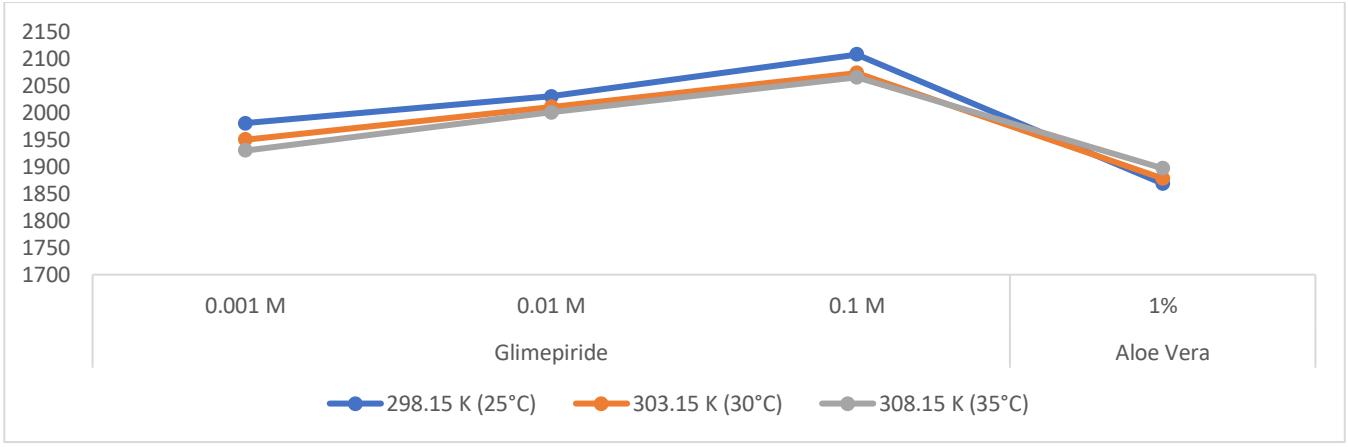

Figure 6: Specific Acoustic Impedance (kg/m²s)

Conversely, Aloe Vera extract shows significantly lower impedance values (1868.50 kg/m²s at 25°C), indicating higher molecular dispersion and weaker cohesive forces. The temperature effect is more pronounced in Glimepiride solutions, with impedance decreasing as temperature increases, suggesting thermal expansion weakens intermolecular interactions. However, for Aloe Vera extract, impedance increases slightly with temperature, implying a structural reorganization that enhances sound wave propagation.

DISCUSSION

The ultrasonic velocity results highlight distinct molecular interactions between Glimepiride and Aloe Vera extract solutions. Glimepiride exhibits higher ultrasonic velocity with increasing concentration, suggesting stronger solute-solvent interactions, enhanced molecular packing, and reduced compressibility. In contrast, Aloe Vera extract shows lower velocity values, indicating weaker interactions due to bioactive compounds that increase solvation and dispersion in water.
Temperature variations affect these solutions differently. Glimepiride shows a slight decrease in velocity with increasing temperature, except at 0.001 M, where a marginal increase at 35°C suggests minor structural reorganization. This decrease is attributed to thermal expansion weakening molecular forces. Meanwhile, Aloe Vera extract shows a consistent increase in velocity with temperature, indicating thermal activation of molecular motion and improved sound wave propagation.
Overall, Glimepiride solutions demonstrate greater structural stability, whereas Aloe Vera extract exhibits higher flexibility and hydration effects. These findings suggest that Glimepiride formulations maintain rigidity under temperature changes, while Aloe Vera extract adapts more readily, which is crucial for drug solubility, stability, and bioavailability in pharmaceutical applications.

The density results provide insight into the solute-solvent interactions and molecular organization of Glimepiride and Aloe Vera extract solutions. As shown in Table 2, the density of Glimepiride solutions decreases slightly with increasing concentration, indicating enhanced solute dispersion and structural reorganization. At 25°C, the density decreases from 1.0500 kg/m³ (0.001 M) to 1.0380 kg/m³ (0.1 M), suggesting that higher solute concentrations promote molecular adjustments to optimize solution stability.

Temperature variations affect density trends differently for both solutions. In Glimepiride solutions, density fluctuates with temperature, likely due to solvent expansion and solute interactions, reflecting complex molecular rearrangements. Meanwhile, Aloe Vera extract solutions consistently exhibit lower density values (1.0150–1.0100 kg/m³), suggesting weaker intermolecular forces and greater solvation effects due to the presence of bioactive compounds.

Overall, Glimepiride solutions demonstrate stronger solute-solvent interactions and structural stability, whereas Aloe Vera extract remains more hydrated and less dense, making it more flexible and adaptable in aqueous environments. These findings have implications for drug formulation and stability in pharmaceutical and nutraceutical applications.

Viscosity is a key parameter that reflects molecular cohesion, solute-solvent interactions, and resistance to flow in solutions. As shown in Table 3, the viscosity of Glimepiride solutions decreases with increasing concentration at 25°C, from 0.950 Pa·s (0.001 M) to 0.890 Pa·s (0.1 M). This suggests that higher solute concentrations enhance molecular dispersion, reducing internal friction within the solution. However, at higher temperatures (30°C and 35°C), viscosity fluctuates slightly, indicating thermal effects on molecular interactions.

For Aloe Vera extract, viscosity remains consistently lower than Glimepiride solutions, ranging from 0.900 Pa·s (25°C) to 0.860 Pa·s (35°C). This trend suggests weaker molecular cohesion and greater solvation effects, likely due to the presence of bioactive compounds that interact with water molecules, reducing overall resistance to flow.
Overall, temperature generally decreases viscosity, as thermal energy disrupts intermolecular forces. Glimepiride solutions show some variations due to solute-specific interactions, whereas Aloe Vera extract demonstrates a steady decline, indicating greater molecular flexibility. These findings are significant for pharmaceutical formulations, as viscosity influences drug solubility, stability, and bioavailability in aqueous media.

Adiabatic compressibility (ß\betaß) provides valuable insight into solute-solvent interactions and the structural integrity of solutions. It is inversely related to ultrasonic velocity, meaning that lower compressibility values indicate stronger molecular interactions and reduced free volume in the solution.

As observed in Table 4, Glimepiride solutions exhibit lower adiabatic compressibility values compared to Aloe Vera extract, confirming stronger solute-solvent interactions and a more rigid molecular structure. At 25°C, compressibility decreases from 2.590E-07 Pa^{-1} (0.001 M) to 2.480E-07 Pa^{-1} (0.1 M), indicating that higher solute concentrations promote tighter molecular packing, reducing the solution's ability to be compressed.

Conversely, Aloe Vera extract shows significantly higher compressibility values (3.800E-07 Pa^{-1} at 25°C), suggesting weaker intermolecular forces and greater hydration effects due to its bioactive components. With increasing temperature, Glimepiride solutions show a slight increase in compressibility, likely due to thermal expansion weakening molecular interactions, while Aloe Vera extract exhibits a steady decrease, indicating increased structural stability at elevated temperatures.

These findings suggest that Glimepiride solutions maintain stronger solute-solvent interactions, while Aloe Vera extract solutions exhibit higher molecular flexibility and hydration, which could impact drug formulation and bioavailability in pharmaceutical applications.

Intermolecular free length (LfL_fLf) is a critical parameter that reflects molecular spacing and solute-solvent interactions. It is directly related to adiabatic compressibility, meaning that higher free length values indicate weaker molecular interactions and greater molecular separation, while lower values suggest stronger interactions and compact molecular packing.

As seen in Table 5, Glimepiride solutions exhibit lower intermolecular free length values compared to Aloe Vera extract, confirming stronger solute-solvent interactions. At 25°C, free length decreases from 1.240E-09 m (0.001 M) to 9.120E-10 m (0.1 M), suggesting that higher concentrations promote tighter molecular packing, reducing intermolecular spacing.

In contrast, Aloe Vera extract shows significantly higher intermolecular free length values (1.540E-09 m at 25°C), indicating weaker solute-solvent interactions and increased hydration effects due to bioactive compounds. With increasing temperature, Glimepiride solutions display minor fluctuations, while Aloe Vera extract exhibits a steady decrease, suggesting that temperature enhances molecular organization in Aloe Vera extract while causing slight expansion in Glimepiride solutions.
These findings highlight that Glimepiride solutions are structurally more stable and compact, while Aloe Vera extract exhibits greater molecular flexibility and hydration, which could influence their respective pharmaceutical and therapeutic applications.

Specific acoustic impedance (ZZZ) is a crucial parameter that evaluates solute-solvent interactions and solution stability by measuring the resistance a medium offers to sound wave propagation. It depends on ultrasonic velocity and density, where higher impedance values indicate stronger molecular

interactions and reduced compressibility, while lower values suggest greater molecular spacing and weaker interactions.
As shown in Table 6, Glimepiride solutions exhibit higher acoustic impedance values compared to Aloe Vera extract, confirming stronger solute-solvent interactions. At 25°C, impedance increases from 1980.00 kg/m²s (0.001 M) to 2107.00 kg/m²s (0.1 M), indicating that higher concentrations lead to denser molecular packing and enhanced rigidity.

Conversely, Aloe Vera extract shows significantly lower impedance values (1868.50 kg/m²s at 25°C), suggesting higher molecular dispersion and weaker cohesive forces due to the presence of bioactive compounds. Glimepiride solutions exhibit a temperature-dependent decrease in impedance, suggesting thermal expansion weakens molecular interactions, whereas Aloe Vera extract shows a slight increase in impedance with temperature, indicating structural reorganization that improves sound wave propagation.

These findings confirm that Glimepiride solutions maintain stronger solute-solvent interactions, while Aloe Vera extract remains more hydrated and flexible, impacting their potential pharmaceutical and nutraceutical applications.

CONCLUSION

This study provides a comprehensive thermoacoustic and ultrasonic characterization of aqueous solutions of Glimepiride and Aloe Vera extract, offering valuable insights into their molecular interactions and stability. The findings suggest that Glimepiride exhibits stronger solute-solvent interactions, contributing to higher structural stability and reduced compressibility, whereas Aloe Vera extract demonstrates higher hydration effects and molecular dispersion. Temperature-dependent changes in ultrasonic velocity, density, viscosity, and related acoustic parameters highlight the impact of thermal energy on molecular organization. These observations are critical for optimizing drug formulations, enhancing bioavailability, and improving the stability of pharmaceutical and plant-based therapies for diabetes management. Future studies should explore additional plant-based combinations to further assess their synergistic potential in diabetes treatment.

REFERENCES

IDF Diabetes Atlas, 10th Edition, 2021.

Atkinson et al., 2014. Type 1 diabetes: new perspectives on disease pathogenesis and treatment. Lancet.

Saeedi et al., 2019. Global and regional diabetes prevalence estimates for 2019 and projections for 2030 and 2045: Results from the International Diabetes Federation Diabetes Atlas, 9th edition. Diabetes Research and Clinical Practice.

Harding et al., 2019. The global burden of diabetes mellitus in the year 2019. Journal of Diabetes Research.

American Diabetes Association, 2021. Standards of Medical Care in Diabetes.

Bailey, C. J., 2017. Metformin: historical overview. Diabetologia.

DeFronzo et al., 2015. Pathogenesis of type 2 diabetes mellitus. Diabetes Care.

Schernthaner et al., 2020. Clinical impact of sulfonylureas in the modern treatment of Type 2 diabetes. Diabetes Therapy.

Grover et al., 2002. Medicinal plants with antidiabetic potential. Journal of Ethnopharmacology.

Sridhar et al., 2011. Herbal plants and their potential to manage diabetes mellitus. Journal of Pharmacy and Bioallied Sciences.

Singh et al., 2020. Plant-based therapies for diabetes mellitus: A review. Phytomedicine.

Joseph and Jini, 2013. Insights into the hypoglycemic effect of traditional Indian herbs used in the treatment of diabetes. Journal of Clinical Medicine.

Leung et al., 2009. A systematic review on the efficacy of bitter melon for diabetes mellitus. Complementary Therapies in Medicine.

Akash et al., 2014. The clinical potential of bitter melon in diabetes management. Diabetes Research and Clinical Practice.

Mason et al., 1998. Ultrasonic interferometry in pharmaceutical analysis. International Journal of Pharmaceutics.

Bhattacharjee and Singh, 2014. Ultrasonic studies on drug solutions: A review. Indian Journal of Physics.