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Comparative Study of Manjistha and Lotus Root Herbal Extract Solutions Using Ultrasonics Technique

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Abstract: Herbal medicines have been broadly consumed since ancient times and the clinically proven by some researches regarding their advantages have been realized by patients for their better therapeutic values with less toxic and adverse effects as compared to contemporary or synthetic medicines. The active components inside the herbs are highly water soluble, huge molecular size, thus resulting into low bioavailability and efficacy. In the present study, our aim is to find the activity of herbal extract of manjistha and lotus by ultrasonic velocity measurement in aqueous medium. The ultrasonic velocity of liquid is fundamentally related to the binding forces between the atoms or molecules. Ultrasonic parameters provide valuable information about various inter and intramolecular interactions in solutions. Intermolecular interaction study plays an important role in development of molecular sciences. The ultrasonic velocity (v), density (ϱ) and viscosity (η) for the aqueous solution of herbal extract of rose of different concentration at 2MHz, 4MHz and 6MHz have been measured at 298.15K, 303.15K and 308.15K. The data is used to evaluate the ultrasonic parameters such as adiabatic compressibility (β), intermolecular free length (L_f), acoustic impedance (Z), relative association (R_A), relative strength (r), relaxation time (τ**)** etc. From ultrasonic velocity, related acoustic parameters for manjistha and lotus root extract solution in water for various concentration at different temperature, The effect of an increases in the temperature appears to increase the excess properties suggesting the presence of specific molecular interaction. These calculated values are interpreted to elucidate the molecular interactions in the liquid mixture and compare the reactivity.

Keywords: Herbal extract, manjistha, lotus root and ultrasonic velocity

1. INTRODUCTION

The application of plants as herbal medicine has been used by various populations throughout human evolution, whereas people started to learn in selecting plants for food, to cure and prevent ailments and diseases. Allopathic medicines are currently used as replacement of traditional medicines, especially in Western developed countries. However, developing countries consume more in traditional medicines due to the high price of synthetic medicines[1-6]. Quinine, digitalis, opium, and aspirin extracted from plants have long history to be used as herbal remedies, and have been developed by various pharmaceutical industries[7].

Herbal extract of manjistha and lotus is medicinally used as eye wash in burning sensation of the eyes, extensively in the cosmetic industry as an ingredient of soap, anti-alcer, antiseptic, blood purifier, gastrointestinal ailments, analgesics, body wash, perfumes, body spray, quicker healing of wounds, anti-microbial activity for glowing skin[8-10].

Herbal extract is a concentrated ingredient of herb blended with water as a suitable solvent to preserve the potency of its active ingredients. This method ensures that the extracts have a much higher shelf life while it is highly concentrated to a required guaranteed potency level. The significance of herbal extract in relation to synthetic drugs is that herbal drugs are absorbed by the body very quickly especially in older adults. A cosmetic is the science of alternation of beauty and has been practiced since last several decades. In India, herbs are widely used for the purpose of worship and sensual enjoyment. Also the herbals are used as whole or part for various ailment of the skin, hair and for overall appearance.[11-14]

Ultrasonic technique is the most important and universally accepted technique to study the physical and chemical properties of solution[15-17]. The measurement of ultrasonic velocity in liquid and liquid mixtures provides valuable information about the physicochemical parameters and the nature of molecular interactions in them[18,19].

Ultrasonic velocity measurements have been widely used in the field of molecular interactions and structural aspects. Number of workers[20,21] have carried out ultrasonic studies of liquid in aqueous as well as non aqueous medium. The molecular interactions of manjistha and lotus root with water as a solvent at 298.15K, 303.15K and 308.15K have been investigated in the present paper. This gives idea about solubility of manjistha and lotus root in solvents like water. By the measurement of ultrasonic velocity, density and viscosity of the solution at 298.15K ,303.15K and 308.15K at 2MHz, 4MHz and 6MHz frequency, the acoustic properties like adiabatic compressibility (β), Specific acoustic impedance (Z), Relative strength (r), Relative association (R_A), Intermolecular free length (L_f) and Relaxation time (τ) are determined.

2. EXPERIMENTAL

All the chemicals used of analytical Grade. Double distilled water was used for the preparation of solutions. A special thermostatic water bath arrangement was made to maintain constant temperature. 1%, 0.5%, 0.25% solutions of rose extract were prepared by taking accurate weights on electronic digital balance. (Model CB/CA/CT-series, Contech, having accuracy ± 0.0001 g).

Ultrasonic velocity of 1%, 0.5%, 0.25% solution of rose extract in water was measured with the Mittal type (Model,M-83,Mittal Enterprizes) multifrequency ultrasonic interferometer at different frequencies with an accuracy of ±2 m/s. All the readings were taken at 298K, 303K, and 308K viscosity of solution was measured by Ostwalds viscometer and density of solution was measured by Digital Densitometer (DMA-35,Anton paar).

By using Density and Ultrasonic velocity, following acoustic parameters are calculated,

Adiabatic compressibility:-

$$\beta = 1/v_S^2 \varrho_S$$

Where v_S= Ultrasonic velocity, ϱ_S = Density of solution

Specific acoustic impedance:-

$$Z = v_S . \varrho_s$$

Where ϱ_s= Density of solution

Intermolecular free length:-

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

Where K= Jacobsons constant, β=Adiabatic compressibility of solution, β_o = Adiabatic compressibility of solvent.

Relative association:-

$$R_A = \varrho_o / \varrho_s (v_o / v_s)^{1/3}$$

Where v_0 = Ultrasonic velocity of solvent

Relaxation time:-

$$\tau = 4 / 3 \beta \eta$$

Where η =Viscosity

Relative strength: -

$$r = 1- (v_S \backslash v_\infty)^2$$

Where vs = velocity, $v_\infty = 1600\ ms^{-1}$

3. RESULTS AND DISCUSSIONS

The experimentally determined values are listed in **Tables 1, 2** and **3**.

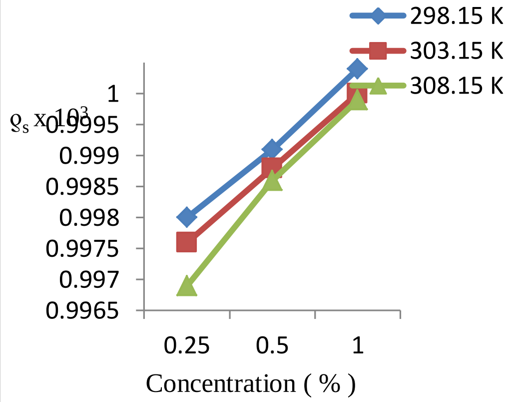

Fig.1 Manjistha H.E.

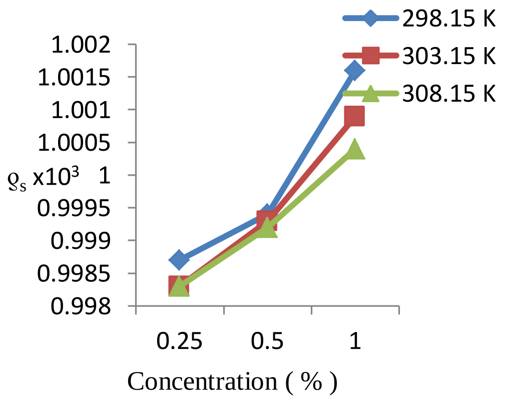

Fig.2 Lotus root H. E.

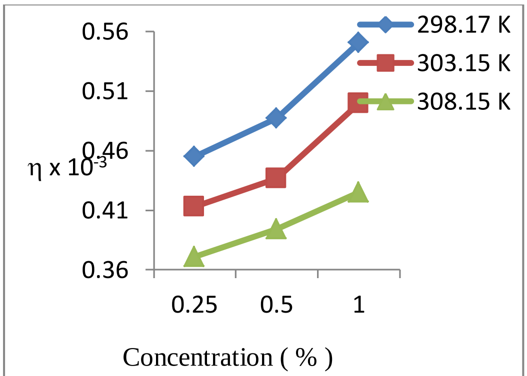

Fig.3 Manjistha H.E.

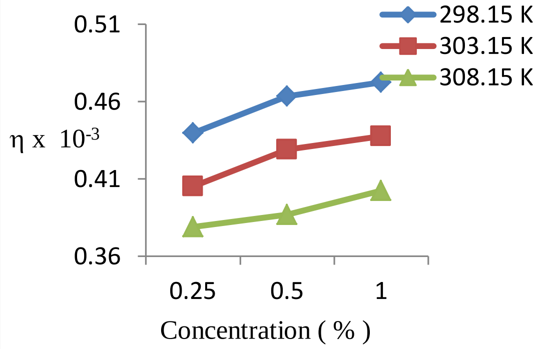

Fig.4 Lotus root H.E.

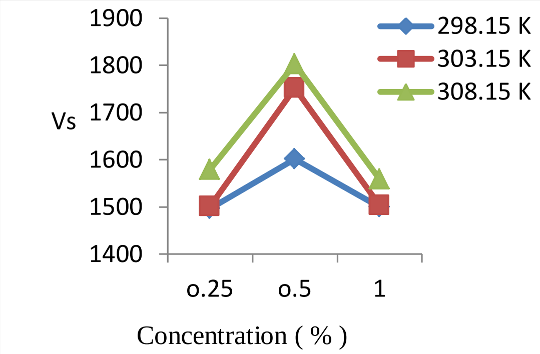

Fig.5 Manjistha H. E. at 2MHz

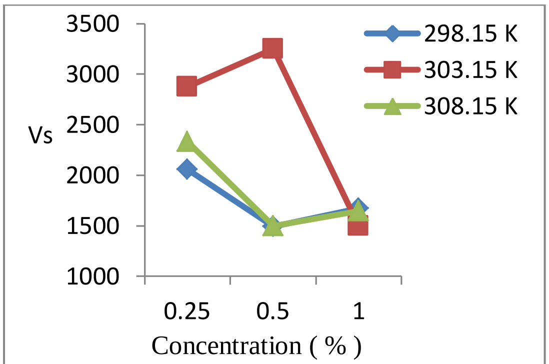

Fig.6 Lotus root H. E. at 2MHz

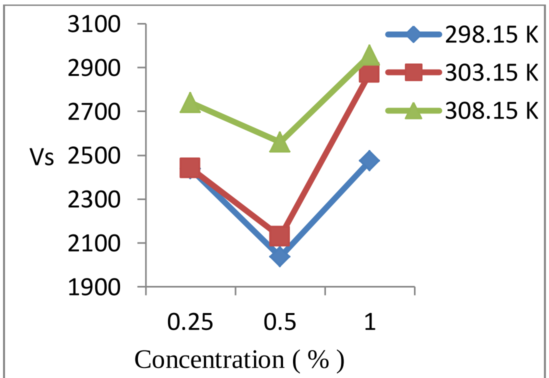

Fig.7 Manjistha H. E. at 4MHz

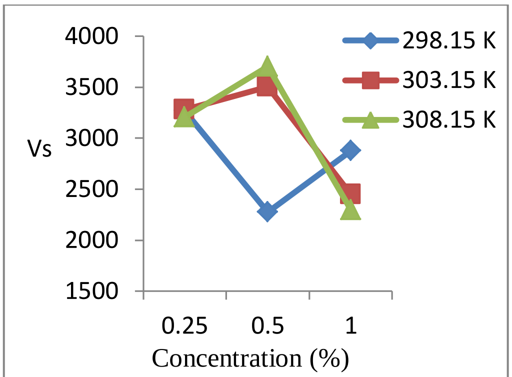

Fig.8 Lotus root H. E. at 4MHz

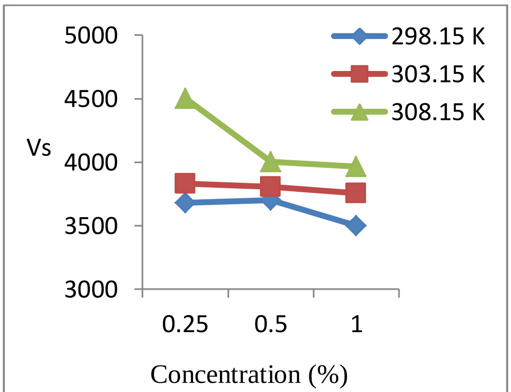

Fig.9 Manjistha H. E. at 6MHz

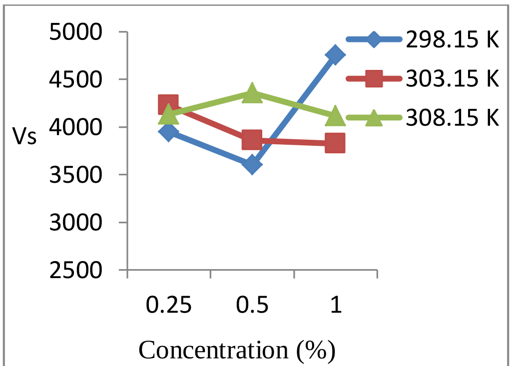

Fig.10 Lotus root H. E. at 6MHz

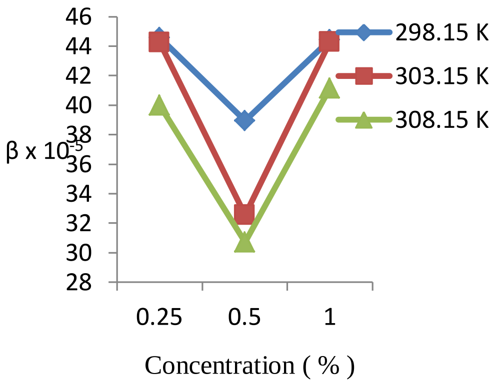

Fig.11 Manjistha H. E. at 2MHz

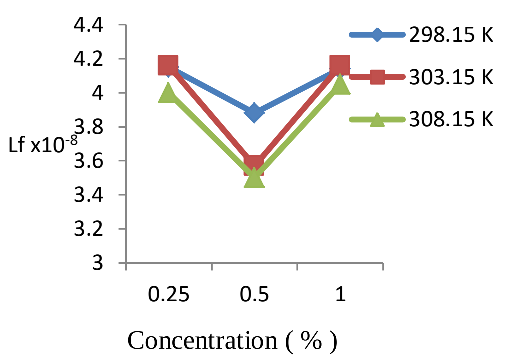

Fig.15 Manjistha H. E. at 2MHz

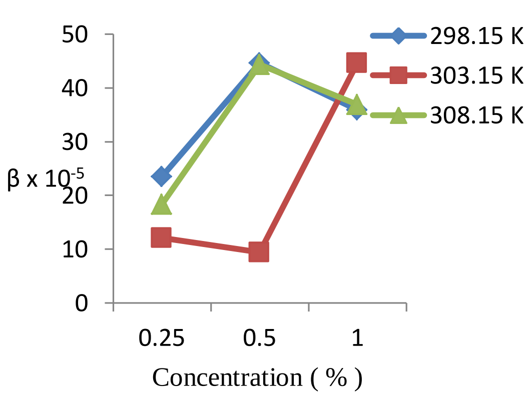

Fig.12 Lotus root H. E. at 2MHz

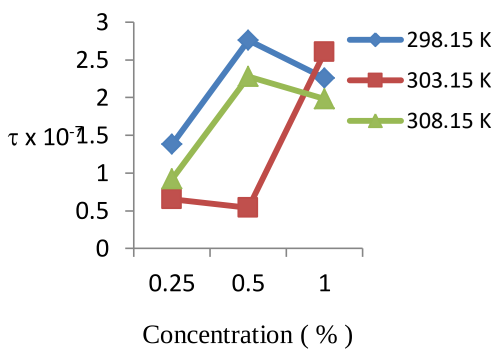

Fig.20 Lotus root H. E. at 2MHz

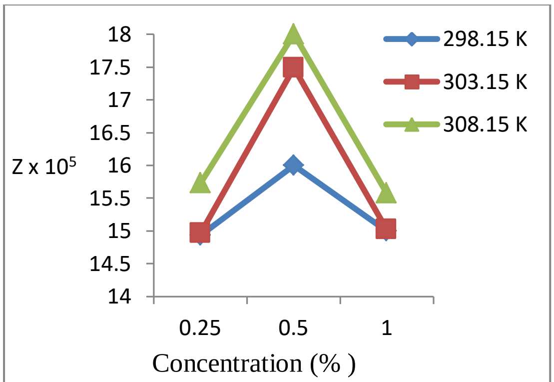

Fig.13 Manjistha H. E. at 2MHz

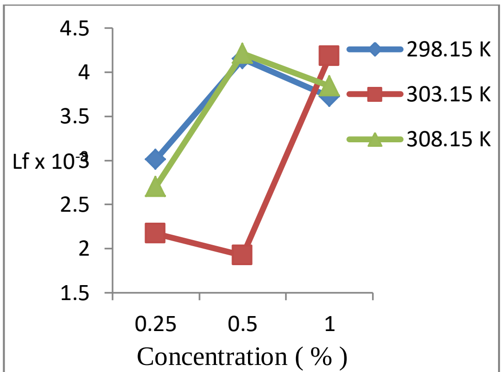

Fig.16 Lotus root H. E. at 2MHz

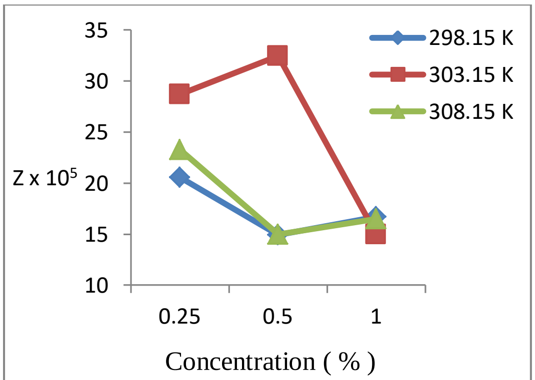

Fig.14 Lotus root H. E. at 2MHz

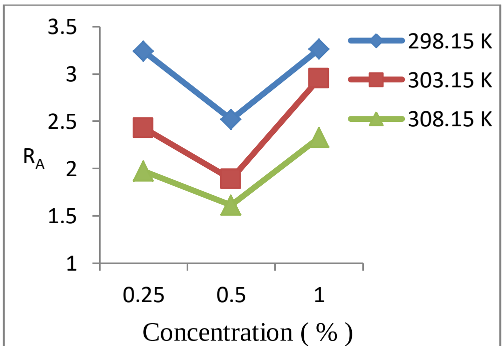

Fig.17 Manjistha H. E. at 2MHz

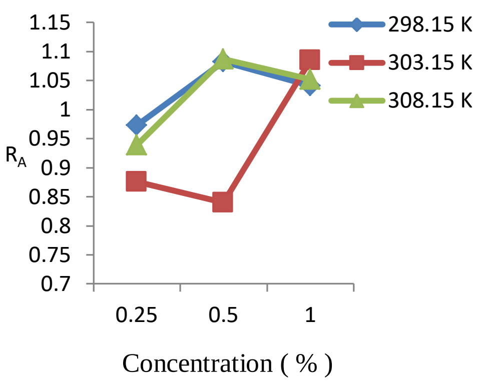

Fig.18 Lotus H. E. at 2MHz

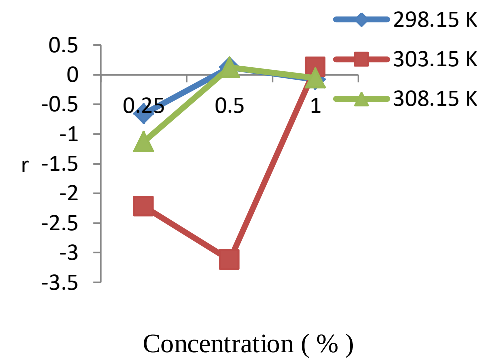

Fig.22 Lotus root H. E. at 2MHz

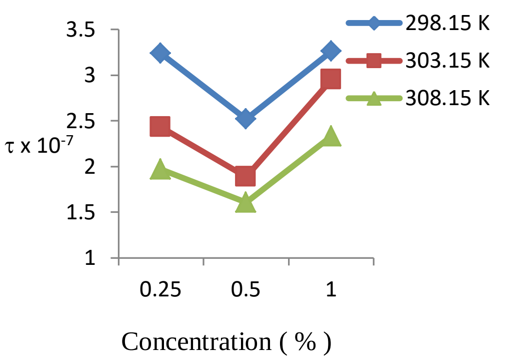

Fig.19 Manjistha H. E. at 2MHz

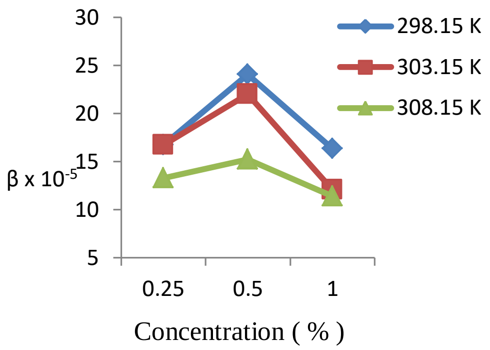

Fig.23 Manjistha H. E. at 4MHz

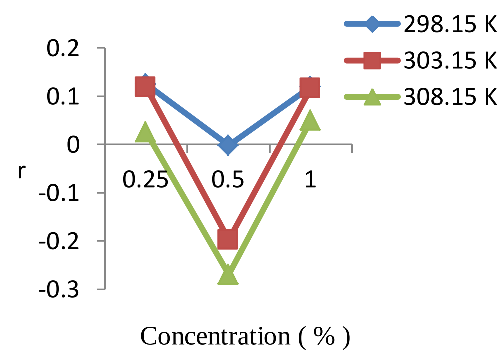

Fig.21 Manjistha H. E. at 2MHz

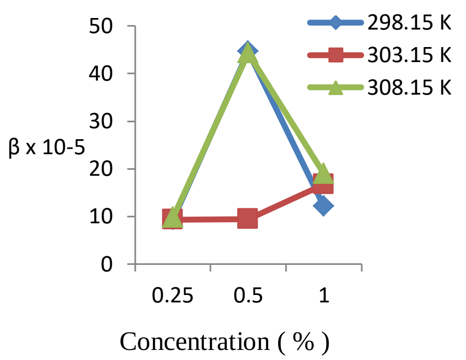

Fig.24 Lotus root H. E. at…

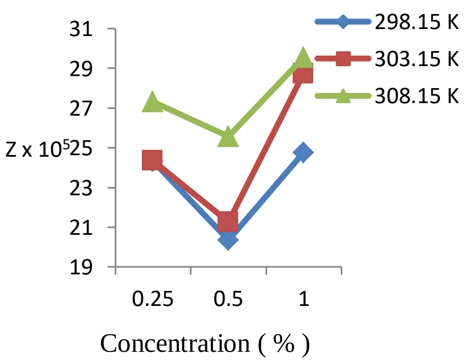

Fig.25 Manjistha H. E. at…

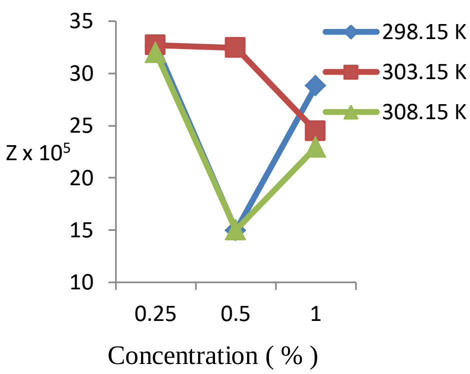

Fig.26 Lotus root H. E. at…

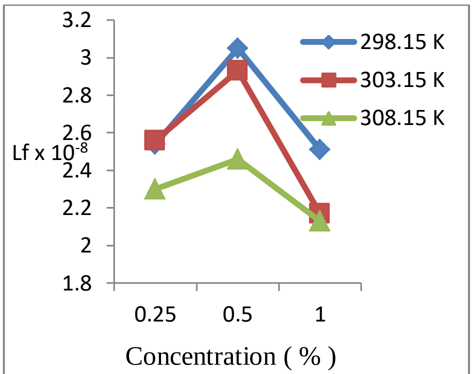

Fig.28 Lotus root H. E. at…

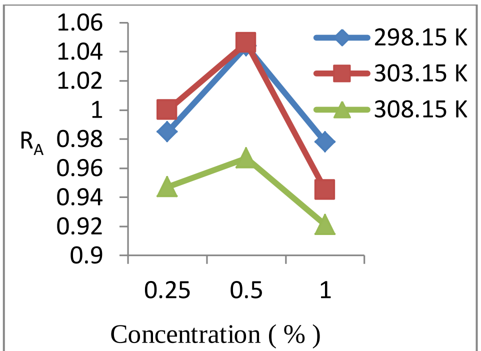

Fig.29 Manjistha H. E. at…

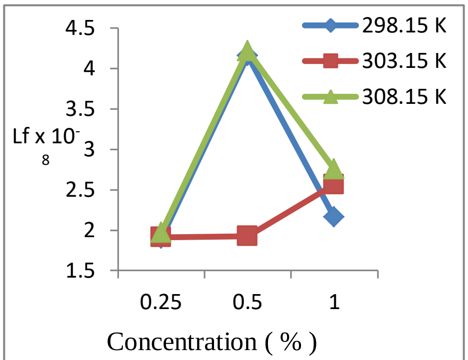

Fig.27 Manjistha H. E. at…

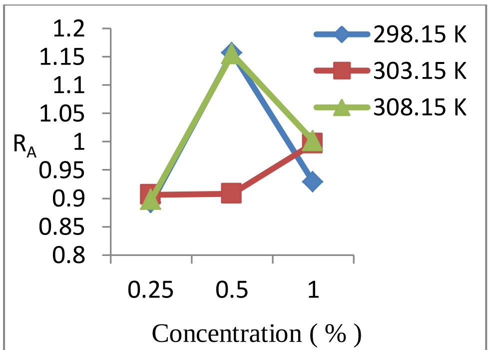

Fig.30 Lotus root H. E. at 4MHz

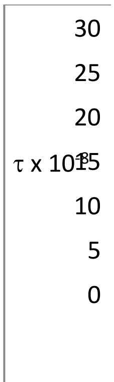

Fig.3

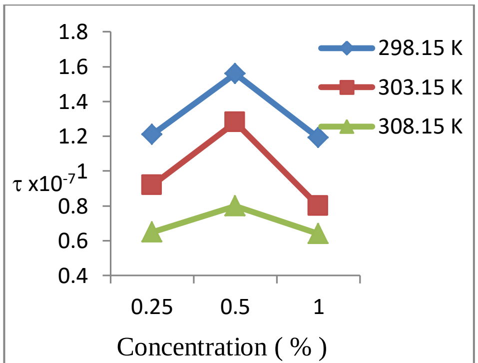

Fig.31 Manjistha H. E. at…

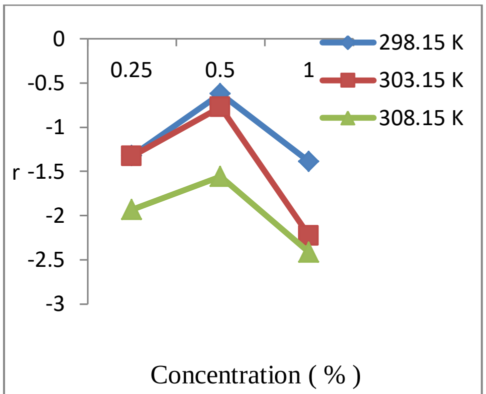

Fig.33 Manjistha H. E. at 4MHz

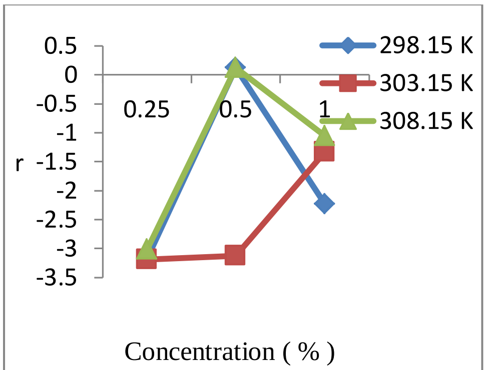

Fig.34 Lotus root H. E. at…

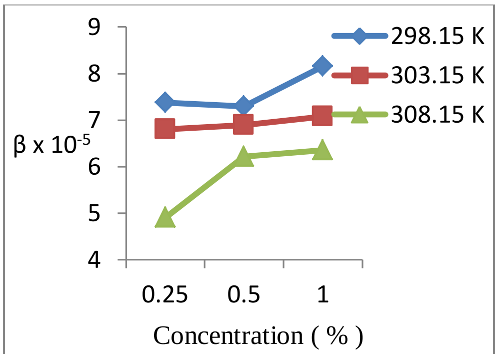

Fig.35 Manjistha H. E. at 6MHz

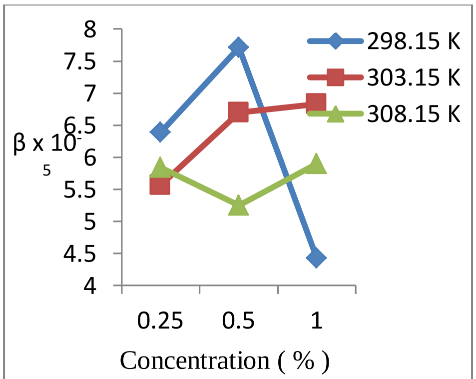

Fig.36 Lotus root H. E. at…

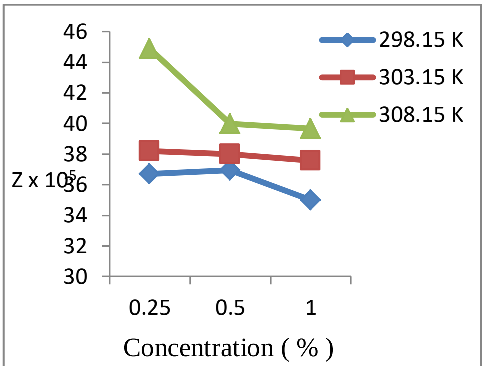

Fig.37 Manjistha H. E. at…

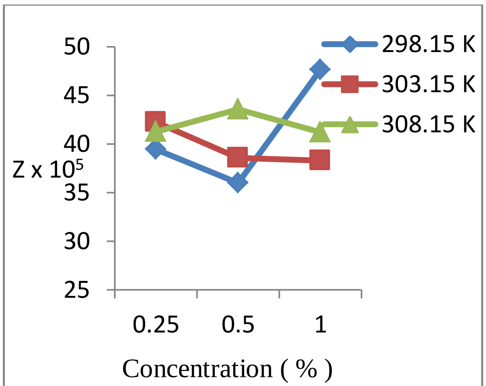

Fig.38 Lotus root H. E. at…

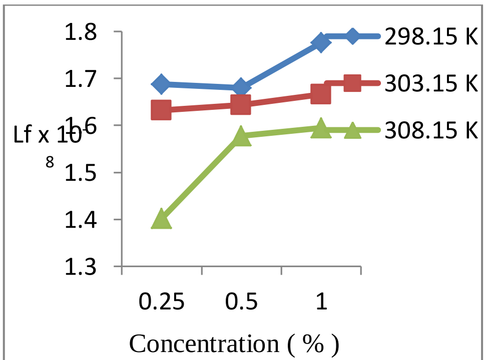

Fig.39 Manjistha H. E. at 6MHz

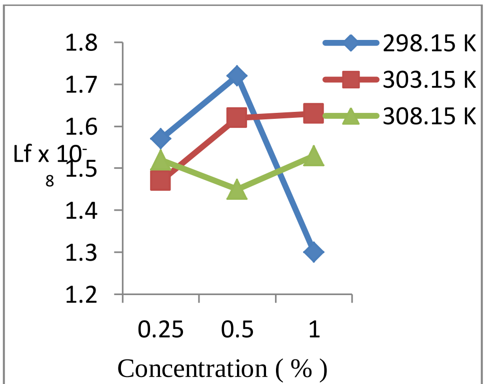

Fig.40 Lotus root H. E. at…

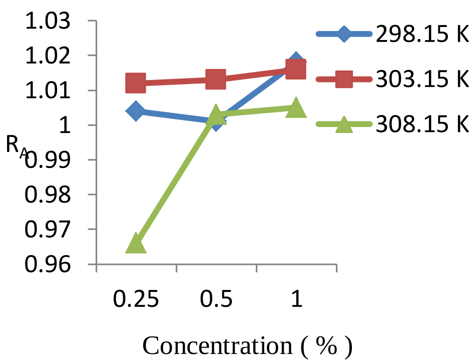

Fig.41 Manjistha H. E. at 6MHz

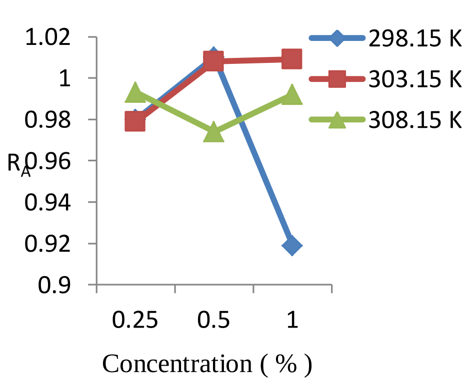

Fig.42 Lotus root H. E. at…

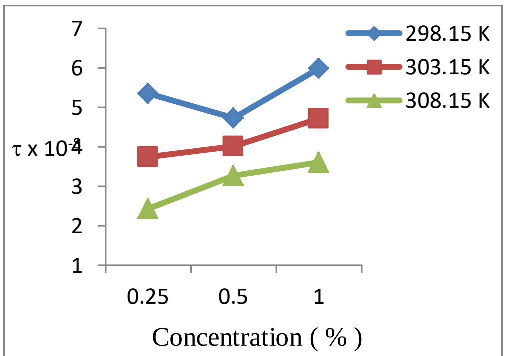

Fig.43 Manjistha H. E. at 6MHz

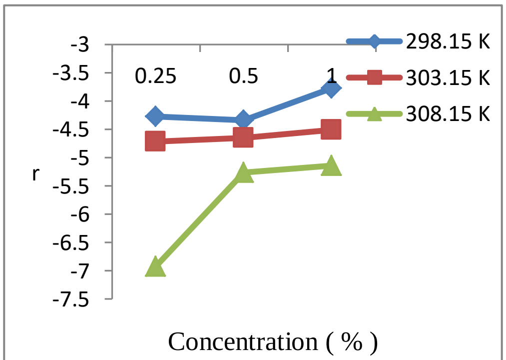

Fig .45 Manjistha H. E. at 6MHz

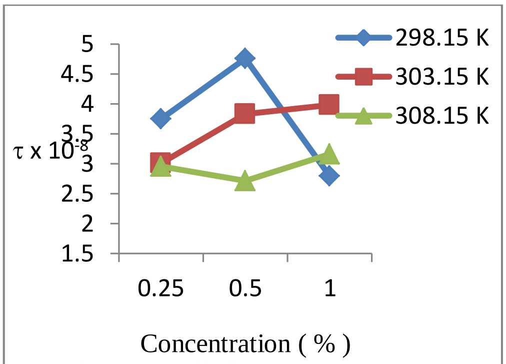

Fig.44 Manjistha H. E. at 6MHz

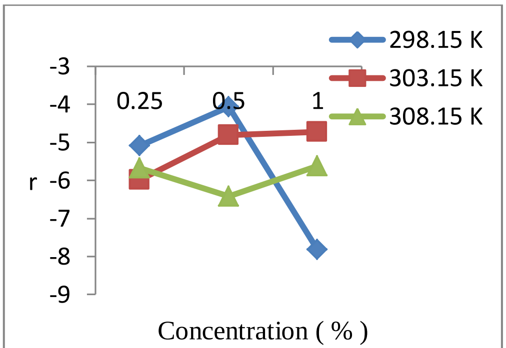

Fig.46 Lotus root H. E. at 6MHz

The values of ultrasonic velocity of manjistha extract solution in water were measured at different temperature, different concentration and different frequencies. From table no.1, 2, 3 and fig.1, 3, 5, 7, 9 it is observed that at different concentrations ultrasonic velocity increases with increase in temperature that gives regular variation graphs at different concentrations, ultrasonic velocity increases with increase in temperature at different frequencies. Viscosity increases with increase in temperature and density decreases with increase in temperature. Ultrasonic velocity, viscosity and density are a parameter in understanding structure as well as molecular interaction occurring in the solution. Manjistha extract solution have ultrasonic velocity increases with increase in temperature at different frequencies, more viscosity and less density, hence there is a strong molecular interaction.

The values of ultrasonic velocity of lotus root extract solution in water were measured at different temperature, different concentration and different frequencies. From table no.1, 2, 3 and fig. no. 2, 4, 6, 8, 10 it is observed that in lotus root extract solution ultrasonic velocity does not increases with increases in temperature. Does not give regular variation in graphs at different concentrations, viscosity of solution is less and density is more, hence there is a less molecular interaction as compare to the manjistha extract solution. This could be due to the energy obtained to overcome the resistance to flow.[22]

The values of adiabatic compressibility (β) of manjistha extract solution in water were calculated at different temperature, different concentration and different frequencies. From table no. 1, 2, 3 and fig. no. 11, 23, 35 it is observed that in manjistha extract solution β value increases with increases in temperature as well as concentration in regular pattern. Also regular variation is observed from graphs because of strong molecular interaction between the solute and solvent hence there is a strong hydrogen bonding between the manjistha extract solution and water.

Thevalues of adiabatic compressibility (β) of lotus root extract solution in water were calculated at different temperature, different concentration and different frequencies. From table no. 1, 2, 3 and fig. no. 12, 24, 36 it is observed that in lotus root extract solution β value does not increase with increases in temperature as well as concentration in regular pattern. Also no regular variation is observed from graphs because of weak molecular interaction between the solute and solvent hence there is a weak hydrogen bonding between the lotus root extract solution and water.

The values of specific acoustic impedance (Z) of manjistha extract solution in water were calculated at different temperature, different concentration and different frequencies and their values are presented in fig. no. 13, 25 and 37. It is observed that the variation of specific acoustic impedance have similar trend as that of velocity. The values of specific acoustic impedance which depend on the molecular packing of the solute and solvent shows that specific acoustic impedance is more, this indicates the presence of a strong interaction due to dipole-induced dipole interactions in manjistha extract and water.[23-25]

The values of specific acoustic impedance (Z) of lotus root extract solution in water were calculated at different temperature, different concentration and different frequencies and their values are presented in fig. no. 14, 26 and 38. The values of specific acoustic impedance is less, this indicates the presence of a weak interaction due to dispersive forces which dominant over dipole-dipole interaction between the lotus root extract and water.

The values of intermolecular free length (Lf) of manjistha extract solution in water were calculated at different temperature, different concentration and different frequencies. It can be seen from fig. no.15, 27 and 39 that intermolecular free length (Lf) decreases linearly on increasing the concentration of solution. As concentration increases, number of ions or particles increases in a given volume leading to the decrease in the gap between two species[26]. This indicates that there is a strong interaction between solute and solvent molecules. This may also imply the decrease in number of free ions, showing the occurrence of ionic association due to strong ion-ion interactions[27]. This indicates the presence of a strong interaction due to dipole-induced dipole interactions in manjistha extract and water.

The values of intermolecular free length (Lf) of lotus root extract solution in water were calculated at different temperature, different concentration and different frequencies. It can be seen from fig. no.16, 28 and 40 that intermolecular free length (Lf) decreases not linearly on increasing the concentration of solution. As concentration increases, number of ions or particles increases in a given volume leading to the increase in the gap between two species. This indicates that there is weak interactions between lotus root extract and water molecules.

The values of relative association (R_A) of manjistha extract solution in water were calculated at different temperature, different concentration and different frequencies. It can be seen from fig. no.17, 29, and 41. It is observed that there is a linear variation of R_A with concentration. Relative association (R_A) is influenced by two factors (i) the breaking up of the solvent molecules on addition of solute to it, and (ii) the solvation of ions that is simultaneously present, the former resulting in decrease and later increase of relative association. The increase of R_A with increase in concentration suggests that solvation of ions predominates over the breaking up of the solvent aggregate on addition of solutes in case of manjistha extract solution.[28]

The values of relative association (R_A) of lotus root extract solution in water were calculated at different temperature, different concentration and different frequencies. It can be seen from fig. no.18, 30 and 42. Reverse trend is observed which may be due to the fact that in this case; it might be possible that, the breaking up of the solvent molecules predominates over the salvation of ions. Solvation number is the number of solvent molecules attached to the central ion by surrendering their translational degree of freedom.

The values of acoustic relaxation time (τ) of manjistha extract solution in water was calculated at different temperature, different concentration and different frequencies. It can be seen from fig. no.19, 31 and 43. The value of acoustic relaxation time increase with increase in temperature and increase with decrease in concentration, this indicates the presence of a strong interaction due to dipole-induced dipole interactions in manjistha extract and water.

The value of acoustic relaxation time (τ) of lotus root extract solution in water was calculated at different temperature, different concentration and different frequencies. It can be seen from fig. no.20, 32, and 44. The value of acoustic relaxation time increase or decrease with increase in temperature and increase or decrease with decrease in concentration, this indicates the presence of a weak interaction due to dipole-induced dipole interactions in lotus root extract and water.

The value of relative strength (r) of manjistha extract solution in water was calculated at different temperature, different concentration and different frequencies. It can be seen from fig. no.21, 33, and 45. The value of relative strength increase with increase in concentration and increase with decrease in temperature, this indicates the presence of a strong interaction due to dipole-induced dipole interactions in manjistha extract and water.

The value of relative strength (r) of lotus root extract solution in water was calculated at different temperature, different concentration and different frequencies. It can be seen from fig. no.22, 34, and 46. The value of relative strength increase or decrease with increase in temperature and increase or decrease with decrease in concentration, this indicates the presence of a weak interaction due to dipole-induced dipole interactions in lotus root extract and water.

CONCLUSION:-

Comparing and analyzing all the values of ultrasonic velocity, density, adiabatic compressibility (β), specific acoustic impedance (Z), intermolecular free length (Lf), relative association (R_A), acoustic relaxation time (τ), and relative strength (r) at 1%, 0.5%, 0.25% concentration, at 298.15K, 303.15K 308.15K temperature and at 2MHz, 4MHz, 6MHz frequencies, it is found that manjistha herbal extract solution contains strong hydrogen bonding, presence of a strong interaction due to dipole-induced dipole interactions. In lotus root herbal extract solution, weak interactions are due to predominance of dispersive force over dipole-dipole interaction. Molecular association or close packing of molecules is operative in manjistha herbal extract solution while dissociation or loose packing of molecules is observed in lotus root herbal extract solution. Interaction is relatively stronger in manjistha herbal extract solution as compare to the lotus herbal extract solution. Therefore manjistha herbal extract solution has great potential as antibacterial agents to skin compared to the lotus herbal extract solution.

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Table 1 : Acoustic Parameters of Manjistha extract solution and Lotus root Extract in water at 2 MHz frequency

Samples	Conc.	Temp.	$\varrho_s \times 10^3$	η x 10^{-3}	Vs	$\beta \times 10^{-5}$	Z $\times 10^5$	Lf $\times$ 10^{-8}	R_A	$\tau \times 10^{-7}$	(r)
Manjistha extract	1	298.15	1.0004	0.5506	1500.33	44.4427	15.0093	4.1456	1.0802	3.2626	0.1207
		303.15	1.000	0.4997	1502.75	44.2819	15.0275	4.1665	1.0855	2.9503	0.1178
		308.15	0.9999	0.4251	1558.74	41.1537	15.5858	4.0593	1.0729	2.3325	0.0509
	0.5	298.15	0.9991	0.4870	1601.91	38.9343	16.0046	3.8802	1.0583	2.5281	-0.0023
		303.15	0.9988	0.4367	1751.59	32.5547	17.4948	3.5725	1.0327	1.8955	-0.1984
		308.15	0.9986	0.3943	1803.19	30.712	18.0066	3.5067	1.0234	1.6146	-0.2701
	0.25	298.15	0.9980	0.4551	1496.18	44.5823	14.9318	4.1521	1.0838	3.2402	0.1255
		303.15	0.9976	0.4128	1501.22	44.2657	14.9761	4.1658	1.0884	2.4363	0.1196
		308.15	0.9969	0.3709	1578.86	39.9912	15.7396	4.0015	1.0715	1.9777	0.0262
Lotus root Extract	1	298.15	1.0016	0.4725	1670.03	35.9125	16.7270	3.7266	1.0411	2.2624	-0.0894
		303.15	1.0009	0.4376	1496.9	44.6689	14.9824	4.1847	1.0859	2.6062	0.1247
		308.15	1.0004	0.4026	1646.74	36.8913	16.4739	3.8433	1.0529	1.9803	-0.0592
	0.5	298.15	0.9994	0.4636	1495.46	44.6879	14.9456	4.1570	1.0825	2.7623	0.1264
		303.15	0.9993	0.4291	3248.7	9.4684	32.4642	1.9266	0.8403	0.5417	-3.1226
		308.15	0.9992	0.3869	1500.7	44.3675	14.9949	4.2148	1.0873	2.2887	0.1202
	0.25	298.15	0.9987	0.4397	2059.3	23.5503	20.5662	3.0178	0.9738	1.3806	-0.6565
		303.15	0.9983	0.4053	2874.02	12.086	28.6913	2.1767	0.8761	0.6531	-2.2265
		308.15	0.9981	0.3789	2333.66	18.3273	23.2922	2.7089	0.9396	0.9258	-1.1273

Abbreviations: Conc.= Concentration in percent, Temp.= Temperature in K, ϱ_s= Density, η= Viscosity in Kg m^{-1} s^{-2} , Vs=Velocity in m/s β=Adiabatic compressibility in pa^{-1}, Z=Specific acoustic impedance in Kgm^{-2} Sec^{-1}, Lf=Intermolecular free length in m, R_A=Relative association, τ =Acoustic relaxation time in sec., r=Relative strength

Table 2 : Acoustic Parameters of Manjistha extract solution and lotus root extract in water at 4MHz frequency

Samples	Conc.	Temp.	$\varrho_s \times 10^3$	η x 10^{-3}	Vs	$\beta \times 10^{-5}$	$Z \times 10^5$	Lf × 10^{-8}	R_A	$\tau \times 10^{-7}$	(r)
Manjistha extract	1	298.15	1.0004	0.5506	2474.45	16.3387	24.7544	2.5136	0.9780	1.1994	-1.3917
		303.15	1.000	0.4997	2875.44	12.0946	28.7544	2.1775	0.9455	0.8058	-2.2297
		308.15	0.9999	0.4251	2957.26	11.4335	29.5696	2.1396	0.9210	0.6480	-2.4161
	0.5	298.15	0.9991	0.4870	2036.34	24.094	20.3450	3.0524	1.0449	1.5645	-0.6197
		303.15	0.9988	0.4367	2129.30	22.0295	21.2674	2.9387	1.0462	1.2827	-0.7710
		308.15	0.9986	0.3943	2560.76	15.2284	25.5717	2.4693	0.9675	0.8006	-1.5615
	0.25	298.15	0.9980	0.4551	2439.06	16.7759	24.3418	2.5470	0.9850	1.2192	-1.3238
		303.15	0.9976	0.4128	2441.64	16.7339	24.3577	2.5613	1.0008	0.9210	-1.3287
		308.15	0.9969	0.3709	2739.72	13.2813	27.3122	2.3060	0.9476	0.6568	-1.9320
Lotus root Extract	1	298.15	1.0016	0.4725	2876.0	12.1019	28.8060	2.1639	0.9291	7.6288	-2.2310
		303.15	1.0009	0.4376	2445.55	16.7361	24.4770	2.5614	0.9970	9.7649	-1.3361
		308.15	1.0004	0.4026	2295.78	18.9807	22.9669	2.7567	1.0016	10.1889	-1.0588
	0.5	298.15	0.9994	0.4636	2276.32	44.6879	14.9456	4.1570	1.1577	27.6231	0.1264
		303.15	0.9993	0.4291	3505.32	9.4684	32.4642	1.9266	0.9085	5.4171	-3.1226
		308.15	0.9992	0.3869	3704.56	44.3675	14.9949	4.2148	1.1553	22.8877	0.1202
	0.25	298.15	0.9987	0.4397	3268.94	9.3459	32.6469	1.9011	0.8929	5.4791	-3.1742
		303.15	0.9983	0.4053	3276.98	9.2963	32.7140	1.9090	0.9068	5.0237	-3.1947
		308.15	0.9981	0.3789	3205.26	9.7151	31.9917	1.9722	0.8983	4.9080	-3.0131

Abbreviations: Conc.= Concentration in percent, Temp.= Temperature in K, ϱ_s= Density, η= Viscosity in Kg m^{-1} s^{-2} , Vs=Velocity in m/s β=Adiabatic compressibility in pa^{-1}, Z=Specific acoustic impedance in Kgm^{-2} Sec^{-1}, Lf=Intermolecular free length in m, R_A=Relative association, τ =Acoustic relaxation timein sec., r=Relative strength

Table 3 : Acoustic Parameters of Manjistha extract solution and Lotus root Extract in water at 6 MHz frequency

Samples	Conc.	Temp.	$\varrho_s \times 10^3$	η x 10^{-3}	Vs	$\beta\times10^{-5}$	Z $\times10^5$	Lf $\times$ 10^{-8}	R_A	$\tau\times10^{-7}$	(r)
Manjistha extract	1	298.15	1.0004	0.5506	3500.58	8.1638	35.0198	1.7768	1.0187	5.9933	-3.7867
		303.15	1.000	0.4997	3757.32	7.0834	37.5732	1.6664	1.0168	4.7194	-4.5146
		308.15	0.9999	0.4251	3965.68	6.3580	39.6528	1.5955	1.0050	3.6037	-5.1432
	0.5	298.15	0.9991	0.4870	3699.69	7.2992	36.9636	1.6800	1.0014	4.7396	-4.3467
		303.15	0.9988	0.4367	3805.09	6.8984	38.0052	1.6445	1.0137	4.0167	-4.6557
		308.15	0.9986	0.3943	4004.85	6.2261	39.9924	1.5789	1.0030	3.2732	-5.2651
	0.25	298.15	0.9980	0.4551	3678.73	7.3745	36.7137	1.6887	1.0044	5.3598	-4.2863
		303.15	0.9976	0.4128	3829.96	6.8009	38.2076	1.6328	1.0128	3.7432	-4.7299
		308.15	0.9969	0.3709	4503.79	4.9146	44.8982	1.4028	0.9662	2.4304	-6.9234
Lotus root Extract	1	298.15	1.0016	0.4725	4753.24	4.4331	47.6084	1.3093	0.9190	2.7929	-7.8255
		303.15	1.0009	0.4376	3828.0	6.8305	38.3144	1.6364	1.0096	3.9853	-4.7240
		308.15	1.0004	0.4026	4117.38	5.9010	41.1902	1.5371	0.9920	3.1677	-5.6221
	0.5	298.15	0.9994	0.4636	3599.91	7.7118	35.9775	1.7269	1.0103	4.7669	-4.0622
		303.15	0.9993	0.4291	3859.32	6.7092	38.5661	1.6218	1.0085	3.8385	-4.8181
		308.15	0.9992	0.3869	4358.76	5.2592	43.5527	1.4511	0.9746	2.7130	-6.4214
	0.25	298.15	0.9987	0.4397	3950.34	6.3998	39.4520	1.5731	0.9802	3.7519	-5.0957
		303.15	0.9983	0.4053	4230.05	5.5791	42.2285	1.4789	0.9791	3.0149	-5.9895
		308.15	0.9981	0.3789	4134.0	5.8402	41.2614	1.5292	0.9930	2.9505	-5.6757

Abbreviations: Conc.= Concentration in percent, Temp.= Temperature in K, ϱ_s= Density, η= Viscosity in Kg m^{-1} s^{-2} , Vs=Velocity in m/s β=Adiabatic compressibility in pa^{-1}, Z=Specific acoustic impedance in Kgm^{-2} Sec^{-1}, Lf=Intermolecular free length in m, R_A=Relative association, τ =Acoustic relaxation time in sec., r=Relative strength