ISSN: 2309-5288 (Print)
ISSN: 2309-6152 (Online)
CODEN: JCLMC4

Journal of Coastal Life Medicine

Application of Thermo-Optical Method in the Estimation of Sugar Content in Carbonated Beverages at Different Temperatures

Received: 25 October 2022, **Revised:** 21 November 2022, **Accepted:** 23 December 2022

Bindu R G
Associate Professor, NSS College, Nilamel, Kollam, Kerala, India

Key Words:
Carbonated Beverages, Thermo-Optical Analysis, Sugar Content, Temperature

Abstract:
Sugar content in commercially available carbonated beverages has been detected and estimated at different temperaturesusing the optical parameters specific optic impedance and specific optical volume using the technique Thermo-Optical Analysis. The analysis has been done by comparing the thermal variation of these parameters of 50:50 wt:wt solutions of glucose and sucrose in distilled water over various concentration ranges(10-35%) with those of beverages. The reliability of this method is then examined.

1. Introduction

Different physical parameters and techniques have been extensively used in past decades to study the thermodynamic properties of liquids and liquid mixtures. The commonly used technique is the ultrasonic method[1-4] which has a wide range of application in science and technology. Thermo-Acoustic Analysis using ultrasonic method has been widely used by researchers in understanding the physico-chemical behaviour of liquids and liquid mixtures[5-8]. Equally important is the Thermo-Optical Analysiswhere the optical method is employed in elucidating the properties of liquids and liquid mixtures.It has been found that a representation in terms of direct parameters has a limited utility whereas a representation in terms of derived parameters provides a better insight into the chemical composition of liquids and liquid mixtures [9]. Moreover literature review shows that very little work has been done in the thermal analysis of optical parameters in studying the characteristics of liquids and liquid mixtures [10-12].Hence in the present study, this technique has been utilized for the estimation of sugar content in carbonated beverages using the derived optical parameters namely specific optic impedance (Z_0) and specific optical volume (ν).

Carbonated beverages contain water, syrup, invert sugars, harmless organic acids and caramel colour[13-19]. Carbonated soft drinks such as Coke, Mirinda, Limcaetc are the major contributors of sugar from all sugar-sweetened beverages. The sweetener added may be fruit juice, fructose corn-syrup, sugar or sugar substitutes. Now-a-days consumption of soft drinks has become a highly visible public health issue. A good amount of sugar content in it causes a rising prevalence of obesity, diabetics, calcium deficiency, dental problems and tooth decay particularly among children and young adolescents aged 12 to 15 years [20]. Though methods like chromatography, calorimetry, enzymatic methods etc are currently available[21] in the estimation of sugar content in substances, the present optical analysis is relatively simple, quick, more reliable and economic.

The present work is an extension of the work done by Prasad et.al [22] in which the sugar content in commercially available beverages is estimated by plotting graphs of concentration versus direct parameters such as ultrasonic velocity (U), refractive index (n) and density (ρ) at one particular temperature viz 26 ^{0}C. This method has the following defects.

(i) They assumed that the beverages contain solutions of 50:50wt:wt mixture of glucose and sucrose. It is not possible to verify whether the beverages contain other substances (additives) in addition to these sugars.

(ii) This method gives only a rough estimate of sugar content because there is no provision for repetition, which is very essential for the estimation of a substance by any physical method.

Hence the present study has been taken to overcome the above demerits. In Thermo-Optical Analysis, we can find whether the carbonated beverages contain only sugars or they contain other substances (additives) in addition to sugars. Moreover, since the estimation of sugar is done at different temperatures using the same derived parameter, the estimated value is more reliable than the estimation using a single direct parameter at a single temperature as reported by Prasad et.al.

2. Materials and Methods

Solutions of 50 : 50 (wt : wt) mixture of glucose and sucrose were prepared in distilled water from10 to 35 percent w/w concentration range. Refractive index and density of the sugar solutions as well as four carbonated beverages namely Coke, Limca, LeherMirinda and Jumpin were measured at six different temperatures from 298K to 323K at an interval of 5K. The temperatures were maintained constant using a thermostatically controlled water circulating arrangement with an accuracy of 0.1K. Density measurements were performed using a 12cc double stem pyknometer and the masses of the solutions were determined using a single pan electronic balance [Dhona 200D] having an accuracy of 0.1mg. The refractive indices were measured using Abbe's Research Refractometer at various temperatures with an accuracy of 0.01%.

Theory

Thermal analysis is a method of physiochemical analysis which is employed in the study of substances and the processes taking place in a substance during heating and cooling. Usually it covers certain specific properties like heat capacity, mass, enthalpy etc [23]. Changes in temperature of a medium change its optical properties. In the present study, thermal analysis has been extended to cover physical parameters namely specific optic impedance (Z_0) and specific optical volume (ν) both are functions of refractive index (n) and density (ρ) of the substances. The specific optic impedance and specific optical volume deduced by Mohanan et.al [24- 25] are given by the equations

$$Z_0 = \frac{120\pi\rho}{n} \quad (1)$$

$$\nu = \frac{n}{\rho^{0.45}} \quad (2)$$

The units of Z_0 and ν are Ω kg m^{-3} and (kg m^{-3})$^{-0.45}$ respectively. The optical parameters are preferred in the study because they are very sensitive to structural changes accompanied by thermal effects.

3. Results and Discussion

The variation of ρ, n, ν and Z_o with temperature for different solutions of glucose: sucrose at different concentrations is tabulated in Table.1. The variation of these parameters with temperature for carbonated beverages is shown in Table.2. The concentration dependence of these parameters has also been depicted in Table.3.

Table 1: Variation of ρ, n, ν and Z_o with temperature for different solutions of glucose: sucrose

Temp (K)	ρ (kgm^{-3})	n	$\nu \times 10^5$ ($(kgm^{-3})^{-0.45}$)	$Z_o \times 10^{-2}$ (Ωkgm^{-3})
100 g/l				
298	1033.36	1.3458	5923.3	2893.2
303	1031.43	1.3455	5927.0	2888.5
308	1029.55	1.3450	5929.7	2884.3
313	1027.02	1.3442	5932.7	2878.9

ISSN: 2309-5288 (Print)
ISSN: 2309-6152 (Online)
CODEN: JCLMC4
Journal of Coastal Life Medicine

318	1025.71	1.3436	5933.5	2876.5
323	1024.24	1.3430	5934.7	2873.7
150g/l				
298	1049.26	1.3520	5909.9	2924.3
303	1047.63	1.3515	5911.8	2920.8
308	1046.03	1.3511	5914.2	2917.2
313	1043.50	1.3504	5917.5	2911.7
318	1041.73	1.3496	5918.5	2908.4
323	1040.38	1.3490	5919.4	2906.0
200g/l				
298	1064.50	1.3579	5897.3	2953.9
303	1062.28	1.3573	5900.2	2949.0
308	1060.82	1.3569	5902.1	2945.8
313	1058.26	1.3563	5905.9	2940.0
318	1056.96	1.3557	5906.6	2937.7
323	1055.55	1.3550	5907.1	2935.3
250g/l				
298	1079.31	1.3637	5885.8	2982.2
303	1076.97	1.3631	5888.9	2977.1
308	1075.26	1.3627	5891.4	2973.2
313	1072.54	1.3622	5896.0	2966.8
318	1071.05	1.3615	5896.6	2964.2
323	1069.71	1.3608	5896.9	2962.0
300g/l				
298	1092.22	1.3684	5874.5	3007.5
303	1089.98	1.3680	5878.2	3002.2
308	1088.29	1.3676	5880.6	2998.4
313	1085.42	1.3670	5885.0	2991.9

ISSN: 2309-5288 (Print)
ISSN: 2309-6152 (Online)
CODEN: JCLMC4
Journal of Coastal Life Medicine

318	1084.10	1.3660	5884.0	2990.4
323	1081.94	1.3652	5885.8	2986.2
350g/l				
298	1105.96	1.3730	5861.2	3035.1
303	1103.83	1.3727	5865.0	3030.0
308	1101.91	1.3724	5868.3	3025.4
313	1098.60	1.3717	5873.3	3017.8
318	1097.36	1.3711	5873.7	3015.7
323	1095.47	1.3701	5874.0	3012.7

Table 2: Variation of ρ, n, ν and Z_o with temperature for different carbonated beverages

Temp (K)	**ρ (kgm^{-3})**	**n**	**$\nu \times 10^5$ ($(kgm^{-3})^{-0.45}$)**	**$Z_o \times 10^{-2}$ (Ωkgm^{-3})**
LeherMirinda				
298	1052.88	1.3530	5905.1	2932.2
303	1050.78	1.3526	5908.7	2927.2
308	1049.42	1.3520	5909.5	2924.7
313	1046.28	1.3513	5914.4	2917.5
318	1044.46	1.3503	5914.6	2914.6
323	1042.84	1.3496	5915.7	2911.5
Coke				
298	1039.81	1.3481	5916.9	2906.3
303	1037.73	1.3479	5921.3	2900.9
308	1036.20	1.3472	5922.2	2898.2
313	1033.60	1.3467	5926.7	2892.0
318	1032.10	1.3459	5927.0	2889.9
323	1030.30	1.3450	5927.7	2886.4
Limca				

ISSN: 2309-5288 (Print)
ISSN: 2309-6152 (Online)
CODEN: JCLMC4
Journal of Coastal Life Medicine

298	1041.29	1.3489	5916.6	2908.7
303	1039.37	1.3483	5918.9	2904.7
308	1037.54	1.3477	5920.9	2900.8
313	1034.85	1.3470	5924.8	2894.8
318	1033.21	1.3462	5925.5	2891.9
323	1031.75	1.3455	5926.2	2889.4
Jumpin				
298	1062.37	1.3566	5897.0	2950.8
303	1060.15	1.3562	5900.8	2945.5
308	1058.79	1.3559	5902.9	2942.3
313	1055.96	1.3555	5908.2	2935.3
318	1054.66	1.3547	5908.0	2933.5
323	1053.36	1.3538	5907.4	2931.8

Table 3: Variation of ρ, n, ν and Z_o with concentration for different solutions of glucose: sucrose at different temperatures

Concentration (%)	**ρ (kgm^{--3})**	**n**	**$\nu \times 10^5$ (kgm^{-3})$^{--0.45}$**	**$Z_o \times 10^{-2}$ (Ωkgm^{-3})**
298 K				
10	1033.36	1.3458	5923.3	2893.2
15	1049.26	1.3520	5909.9	2924.3
20	1064.50	1.3579	5897.3	2953.9
25	1079.31	1.3637	5885.8	2982.2
30	1092.22	1.3684	5874.5	3007.5
35	1105.96	1.3730	5861.2	3035.1
303 K				
10	1031.43	1.3455	5927.0	2888.5
15	1047.63	1.3515	5911.8	2920.8

ISSN: 2309-5288 (Print)
ISSN: 2309-6152 (Online)
CODEN: JCLMC4
Journal of Coastal Life Medicine

20	1062.28	1.3573	5900.2	2949.0
25	1076.97	1.3631	5888.9	2977.1
30	1089.98	1.3680	5878.2	3002.2
35	1103.83	1.3727	5865.0	3030.0
308 K				
10	1029.55	1.3450	5929.7	2884.3
15	1046.03	1.3511	5914.2	2917.2
20	1060.82	1.3569	5902.1	2945.8
25	1075.26	1.3627	5891.4	2973.2
30	1088.29	1.3676	5880.6	2998.4
35	1101.91	1.3724	5868.3	3025.4
313 K				
10	1027.02	1.3442	5932.7	2878.9
15	1043.50	1.3504	5917.5	2911.7
20	1058.26	1.3563	5905.9	2940.0
25	1072.54	1.3622	5896.0	2966.8
30	1085.42	1.3670	5885.0	2991.9
35	1098.60	1.3717	5873.3	3017.8
318 K				
10	1025.71	1.3436	5933.5	2876.5
15	1041.73	1.3496	5918.5	2908.4
20	1056.96	1.3557	5906.6	2937.7
25	1071.05	1.3615	5896.6	2964.2
30	1084.10	1.3660	5884.0	2990.4
35	1097.36	1.3711	5873.7	3015.7
323 K				
10	1024.24	1.3430	5934.7	2873.7
15	1040.38	1.3490	5919.4	2906.0

ISSN: 2309-5288 (Print)
ISSN: 2309-6152 (Online)
CODEN: JCLMC4
Journal of Coastal Life Medicine

20	1055.55	1.3550	5907.1	2935.3
25	1069.71	1.3608	5896.9	2962.0
30	1081.94	1.3652	5885.8	2986.2
35	1095.47	1.3701	5874.0	3012.7

The variation of ν and Z_0 with temperature for different concentrations of 50:50 glucose - sucrose solutions as well as those of carbonated beverages is plotted in Fig.1 and Fig.2. In Fig.1,for sugar solutions, the curves are smooth while for the beverages, there is a slight change in the slope of the curve at a particular temperature 308K. Also there is a slight change in the general shape of the curves of beverages with those of sugar solutions. This may be due to the presence of preservatives or other additives in the beverages. The change in slope at 308K is maximum for Coke and minimum for Jumpin. This is due to the difference of levels of additives present in the beverages other than sugars. However the overall shape of the beverages and sugar solutions are the same.

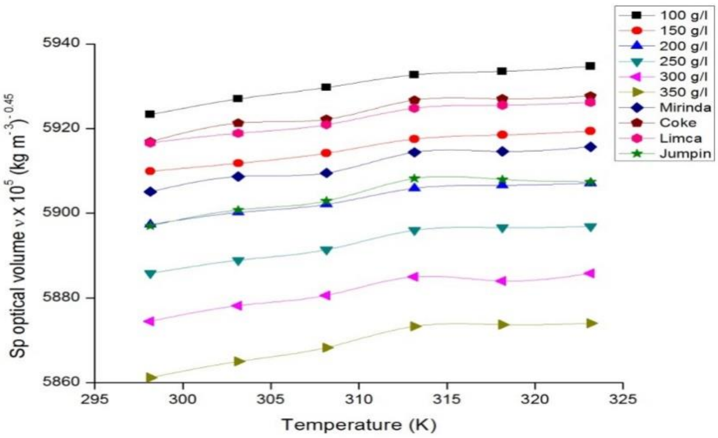

Figure 1: Variation of ν with temperature for beverages and different concentrations of sugar solutions.

A rough estimate of sugar content can be obtained from Fig.1. It can be found from the graph that the concentration of sugar content inCoke and Limcalies in between that of 10% and 15% whereas for Mirinda and Jumpin, it comes in between that of 15% and 20%. Roughly the concentration of sugar in Mirinda is in the range of 16.5%, Coke 12%,Limca 12.5% and Jumpin 19.5%.

Fig.2 shows the thermal variation of Z_0 for different concentrations of sugar solutions along with that of beverages. Though the general shape of the curve is the same for all, the graphs of beverages show a slight change in slope at 308K compared with that of sugar solutions. This shows that the thermal variation of Z_0 is also sensitive to the presence of additives in carbonated beverages. Here also the general shape of the curves for different concentrations of sugar solutions and beverages is the same. A rough estimation of the sugar content in the beverages from Z_0 versus temperature graph shows that Jumpin has a maximum in the range 19.5%, Coke and Limca in the range of 12% and 12.5% respectively and Mirinda in the range of 16.5%.

ISSN: 2309-5288 (Print)
ISSN: 2309-6152 (Online)
CODEN: JCLMC4
Journal of Coastal Life Medicine

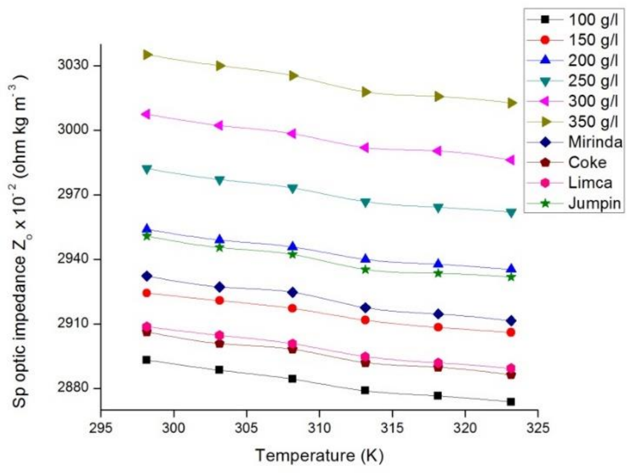

Figure 2: Variation of Z_0 with temperature for beverages and different concentrations of sugar solutions

An accurate estimation of sugar content in carbonated beverages at different temperatures can be obtained from ν and Z_0 versus concentration graphs. The estimation at one particular temperature – 303K for Jumpin is shown in Figs. 3 (a & b).

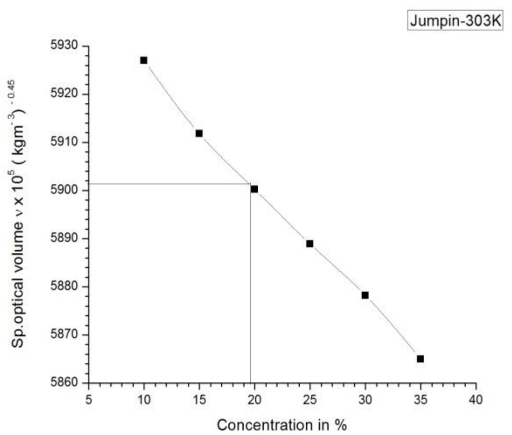

Fig.3(a)

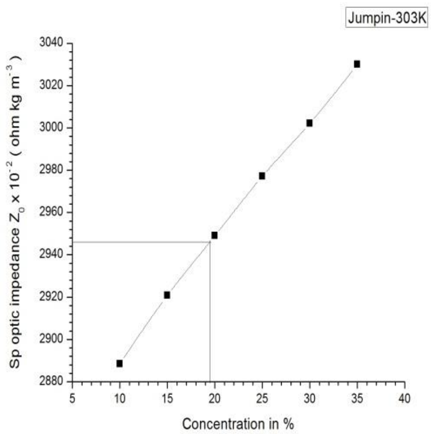

Fig. 3(b)

Figure 3(a) Variation of ν with concentration of sugar solutions at 303K

Figure 3(b) Variation of Z_0 with concentration of sugar solutions at 303K

The estimated percentage of sugar content in the carbonated beverages at various temperatures are given in Table 4

Table 4: Percentage of sugar content in different carbonated beverages at temperatures from 298K to 323K

Temp K	LeherMirinda		Coke		Limca		Jumpin	
	Using ν in %	Using Z_0 in %	Using ν in %	Using Z_0 in %	Using ν in %	Using Z_0 in %	Using ν in %	Using Z_0 in %

298	16.9	17	12.3	12.2	12.9	12.9	19.6	19.5
303	16.4	16.2	12	12.1	12.6	12.5	19.5	19.4
308	16.3	16.1	11.9	12.1	12.5	12.5	19.5	19.4
313	16.2	16.1	12	12	12.5	12.4	19.2	19.3
318	16.2	16	12	12	12.5	12.4	19.2	19.3
323	16.2	16	11.9	11.9	12.4	12.3	19	19.2

4. Conclusion

Thermo-Optical Analysis gives an insight into the presence of additives in carbonated beverages other than sugars. The estimated values of sugar content in carbonated beverages at different temperatures using the thermal variation of derived optical parameters ν and Z_0 are in good agreement. Moreover this method is more reliable compared to the estimation of sugar in beverages at a single temperature from the direct parameters.

References

[1] Babu P, PrabhakaraRao N, Chandrasekhar G and BhanuPrakash B (2022) Ultrasonic studies in the ternary mixtures: water + iso-propanol + pyridine at 303.15 K, *Chemical Thermodynamics and Thermal Analysis*, 5: 1-9.

[2] Sudhir P Dange, Pradip D Borkar and Omprakash P Chimankar (2021) Physico-chemical analysis on binary liquid mixture of nicotinic acid at different temperatures, *Indian Journal of Pure & Applied Physics*, 59: 132-137.

[3] Kolhe R K and Bhosale B B (2020) Study of excess parameters of binary mixtures of DMSO with hexanol-1-ol using ultrasonic method at various temperatures, *Journal of Engineering Sciences*, 11(4): 1350-1356.

[4] SanghamitraPradhan, ManaswiniChhotaray and Sujata Mishra (2020) An insight on thermo physical properties of binary mixtures of hydrocarbons with spectroscopic evidence; essential components of transformer oils, *Materials International*, 2(2): 83-96.

[5] SampandamElangovan (2021) Density, ultrasonic velocity, isentropic compressibility, molar volumes and related excess parameters studies on ethyl acetate with 1-ethanol at 303K, 308K and 313K, *Material Science Research India*, 18(2): 171-178.

[6] SavithaJyostna T, Satheesh B, Sreenu D, Ramesh G and Jayanthi Rani E (2020) The study of thermo-physical properties of binary liquid mixtures of isoamyl alcohol with amines at 298.15K-308.15K, *Physics and Chemistry of Liquids*, 58(3): 349-363.

[7] Shakila A, Ravikumar S, Pandiyan V and Gaba R (2019) Thermodynamic properties of binary liquid mixtures containing aromatic alcohol and aliphatic amines at different temperatures, *Journal of MolecularLiquids*, 285(1): 279-287.

[8] Praharaj M K (2021) Study of molecular interaction in aqueous KCl at different temperatures, *Journal ofScientific Research*, 13(1): 1-8.

[9] Pitzer K S (1995) Thermodynamics, 3rdEdn. McGraw Hill Book Co; New York.

[10] Shivappa BHalligudi, Tejraj M Aminabhavi, Manjeshwar L S and Balundagi R H (2019) Thermodynamic and optical properties of binary liquid mixtures, *Indian Journal of Chemistry Section A*, 27A(1988): 303-307.

[11] Tanya L Myers, Bruce E Bernacki, Michael J Wilhelm and Karissa L Jensen(2022) Influence of intermolecular interactions on the complex index of refraction for binary liquid mixtures in the infrared, *Physical Chemistry, Chemical Physics*, 24(36): 22206-22221.

[12] Reza VakiliNezhaad G, Morteza Mohammad ZaheriFarzanehMohammadi and Mohammad Humaid (2022) Density and refractive index of binary ionic liquid mixtures with common

ISSN: 2309-5288 (Print)
ISSN: 2309-6152 (Online)
CODEN: JCLMC4
Journal of Coastal Life Medicine

cations/anions along with ANFIS modeling, *Liquids*, 2(4): 432- 444.

[13] Jing Wen Huijuan Ma, Yindjie Yu, Xiaoxuan Zhang and DandanGuo (2021) Sugar content of market beverages and children's sugar intake from beverages in Beiing, China, *Nutrients*, 13(12) 4297 doi:10.3390/nu13124297

[14] Abhijit Panda, HemamaliniRath, ShilpaMahapatra and Manikesh Mishra (2021) Association between consumption of carbonated beverages and dental erosion – A systematic review, *Journal of Indian Association of Public Health Dentistry* , 19(4): 240. doi: 10.4103/jiaphd.jiaphd_17_21.

[15] Thomas S Kuntzlemann and Jacob T Kuntzlemann (2021) Ethanol as a probe for the mechanism of bubble nucleation in the diet coke and mentos experiment, *Molecules*, 26(6):1691. doi: 10.3390/molecules26061691

[16] Tahmassebi J F and BaniHani A (2020) Impact of soft drinks to health and economy: A critical review, *European Archives of Paediatric Dentistry*, 21: 109-117.

[17] Thomas S Kuntzlemann and Andria Sturgis (2020) Effect of temperature in experiments involving carbonated beverages, *Journal of Chemical Education*, 97(11): 4033-4038.

[18] Tinging Zhang, ShanshanBian, YeqingGu and GeMeng (2020) Sugar-containing carbonated beverages consumption is associated with hyperuricemia in general adults: A cross-sectional study, *Nutritional metabolism and cardiovascular diseases*, 30(10): 1645 -1652.

[19] Nur Nabila Abdul Wahab, NurAfiqahRosmanAnnapurnyVenkiteswaran and Norashikin Abu Bakar (2019) The effect of temperature and exposure time on the pH of beverages: A pilot study, *ProceedingBook of the 9th Dental Student's Scientific Symposium*, 1: 12 -13.

[20] Lenny R Vartanian, Marlene B Schwartz and Kelly D Brownell (2007) Effects of soft drink consumption on nutrition and health: A systematic review and meta-analysis, *Am J Public Health*, 97(4): 667-675. doi: 102105/AJPH 2005.083782.

[21] Povey M J W and Mc Clements D J (1988) Ultrasonics in food engineering. Part I: Introduction and experimental methods, *Journal of Food Engineering*, 8(4): 217-245.

[22] Prasad K, Nath N and Prasad K (2000) Estimation of sugar content in commercially available beverages using ultrasonic velocity measurement, *Indian Journal of Physics*, 74A(4): 387- 389.

[23] Anthony R West (1988) Basic Solid State Chemistry, John Wiley & Sons, Chichester, pp 196.

[24] Mohanan S, Vaidyan V K and Kurian K V (1997) A study on specific optic impedance of materials, *Applied Physics Letters*, 70(7): 805-807.

[25] Mohanan S, Vaidyan V K and Kurian K V (1997) A study on two new liquid parameters H and N and their dependence on molecular structure, *Acusticsactaacustica*, 83(2): 367-373.