Arabian Journal of Chemistry (2014) 7, 272–276

King Saud University

Arabian Journal of Chemistry

www.ksu.edu.sa
www.sciencedirect.com

ORIGINAL ARTICLE

Ultrasonic investigation on aqueous polysaccharide (starch) at 298.15 K

S. Nithiyanantham [a,*], L. Palaniappan [b]

[a] School of Applied Physics (Ultrasonics/Bio-Physics Division), SRM University, Kattankulathur, Tamilnadu, India
[b] DDE, Department of Physics, Annamalai University, Annamalainagar, Tamilnadu, India

Received 11 August 2010; accepted 30 October 2010
Available online 9 November 2010

KEYWORDS

Ultrasonic velocity;
Acoustic parameters;
Starch

Abstract The ultrasonic velocity, density and viscosity at 298.15 K have been measured in the binary system of starch in aqueous medium. The acoustical parameters such as adiabatic compressibility (β), free length (L_f), free volume (V_f), internal pressure (π_i), acoustical impedance (Z), relative association (R_A), Rao's constant (R), Wada's constant (W), classical absorption coefficients (α/f^2), relaxation time (τ) and relaxation strength (r) are calculated. The results are interpreted in terms of molecular interaction between the components of the mixtures.

1. Introduction

Ultrasonic analysis of biological specimens began at the end of the First World War. There were substantial works on tissue studies in recent past, especially by Floyd Dunn (1976) and his group. Survey of literature (Pholman, 1939; Hueter, 1948) reveals that there have been five broad divisions of bio-acoustical studies of which the present work deals with the Characterization of the specimen using the sound velocity. The magnitude of density as well as the velocity of sound in human body fluids or constituents is of vital importance for carrying out acoustical analysis of human system or organs (Ludwig, 1950; Jasvir Singh and Bhatti, 1998; Singh and Behari, 1994; Kirti Ghandhi Bhatia et al., 2002; Palaniappan and Velusamy, 2004) since sudden excess or reduction of velocity of the wave indicates some abnormality (Jerie et al., 2004; Panday et al., 2004). The Carbohydrate (starch) splitting enzymes must break down the linkages in order to form simple products (Carl et al., 1998), these are mostly α-amylases (or) by hydrolysis, found both in the salivary and in the pancreatic juice (Chakrabarthi et al., 1972). It is also activated by chloride with the help of Ca^{2+} ions. Another type of amylase recognized as β amylase, acts only at the terminal reducing end of a polyglucan chain found in plants. Animal amylases including those present in human tissues are α-amylases. They attack α-1, 4 linkages in a random manner anywhere along the polyglucan chain (Jain, 1998). But, this present work deals only with hydrolysis.

2. Sample preparation and experimental techniques

A 1–6% standard solution of amylase, in steps of 1% was prepared initially. All the solutions are left for 2 h and complete solubility is found (Walter Moore, 1962). The ultrasonic veloc-

* Corresponding author. Tel.: +91 04366 276914.
E-mail address: s_nithu59@rediffmail.com (S. Nithiyanantham).

Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

1878-5352 © 2010 Production and hosting by Elsevier B.V. on behalf of King Saud University.
http://dx.doi.org/10.1016/j.arabjc.2010.10.030

Nomenclature

kT	temperature dependent constant	β	adiabatic compressibility
k	temperature independent constant	L_f	free length
Meff, M	effective molecular weight	V_f	free volume
x	mole fraction	π_i	internal pressure
i	component	T	temperature
m	molality	R	Universal gas constant
m	molecular weight	b	atomic scaling factor

ity (U) in the liquid mixtures have been measured using an Ultrasonic interferometer (Mittal type – 82, New Delhi, India) working at 2 MHz frequency with accuracy ± 0.1 ms^{-1}. The density (ρ) and viscosity (η) are measured using a Pycknometer and an Ostwald's viscometer of accuracy of ± 0.1 kg m^{-3} and ± 0.001 mN s m^{-2} respectively. Using the measured data, the acoustical parameters such as adiabatic compressibility (β), free length (L_f), free volume (V_f) and internal pressure (π_i), acoustical impedance (Z), relative association (R_A), Rao's constant (R), Wada's constant (W), classical absorption coefficients (α/f^2), relaxation time (τ) and relaxation strength (r) have been calculated using the following expressions (1)–(11).

$$\beta = 1/U^2\rho \quad (1)$$

$$L_f = kT(\beta)^{1/2} \quad (2)$$

$$V_f = (Meff\,U/\eta k)^{3/2} \quad (3)$$

$$\pi_i = bRT(k\eta/U)^{1/2}/(\rho^{2/3}/M^{7/6}) \quad (4)$$

where b is the atomic cubic factor = 2.

$$Z = U_\rho \quad (5)$$

$$R_A = \rho/\rho_0(U_0/U)^{1/3} \quad (6)$$

$$R = U^{1/3}V \quad (7)$$

$$W = \beta^{1/7}V \quad (8)$$

$$(\alpha/f^2) = (8\pi 2\eta/3\rho U^3) \quad (9)$$

$$\tau = (4\eta s/3\rho U^2) \quad (10)$$

and

$$r = 1 - (U/U_\alpha)^2 \quad (11)$$

where U_α = 1600 ms^{-1}.

The starch, supplied by S.D. fine Chem. has been taken in the forms of solutions. Double distilled water is used throughout the work.

3. Results and discussion

Table 1 lists the measured values of various percentages (1–6%) of starch solution having the same clusters of maltose and glucose molecules. As the molecular weight of these polysaccharides are in order of lakhs of units (1,000,00) and their solubility in water is relatively very low (Jain, 1998), percentage composition is preferred along with the procedure given in standard preparation techniques of starch solution (Kim et al., 2001).

The perusal of Table 1 clearly shows that all the measured parameters, sound velocity (U), density (ρ) and viscosity (η) increases with increase in % of starch. The increase in starch molecules makes the medium to be denser. This leads to less compressibility and hence sound velocity also increases. Further, the increase in the number of particles simply increases the cohesion between the layers of the medium and so the co-efficient of viscosity increases. Thus, the existence of particle-particle interaction is suspected and this observation is further supported by the non-linear increase in the trend of the measured parameters.

A clear look at the Table 1 suggests that the range of sound velocity variation with percentage composition is almost same for all percentages of starch. Considering the density variation, for a given % composition, the maximum densities are recorded for 6% and lower for 1%. The same trend is obtained for viscosity variation and seems this is to be % dependent of the solute.

All these structural variations are reflected in the observed trend. From the same Table 1, the co-efficient of viscosity of the liquid is one of the peculiar properties that determine the inner nature of the medium. Starch has a higher viscosity at higher concentration, i.e., the molecules of starch have a highly cohesive nature.

As regards the surface area of the starch the number of glucose units is large, it may lead to a notion that the effective

Table 1 Measured values of ultrasonic velocity (U), density (ρ) and viscosity (η), some calculated values of adiabatic compressibility (β), free length (L_f), free volume (V_f), internal pressure (π_i), for various percentages (%) of starch in water at 298.15 K.

%	U (m s^{-1})	ρ (kg m^{-3})	$\eta \times 10^3$ N s m^{-2}	$\beta \times 10^{10}$ N^{-1} m^2	$L_f \times 10^{11}$ m	$V_f \times 10^8$ m^3 mol^{-1}	$\pi_i \times 10^{-9}$ N m^{-2}
1	1517.8	1001.3	0.981	4.335	4.154	1.685	2.798
2	1521.2	1006.8	1.000	4.292	4.134	1.666	2.800
3	1524.3	1012.3	1.026	4.252	4.114	1.632	2.812
4	1528.7	1018.2	1.051	4.202	4.090	1.604	2.821
5	1531.2	1021.8	1.870	4.174	4.077	0.688	3.726
6	1533.7	1027.5	2.550	4.137	4.058	0.439	4.316