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Viscometric and Ultrasonic study of isolated rice protein in aqueous solutions

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Abstract

Density (ρ), viscosity (η) and Sound velocities (u) were measured in the aqueous solutions obtained after isolation of starch from rice flour at 287.79 K. The studies were carried out to investigate interaction of proteins present in rice flour along with other biomolecule. The acoustical parameter such as adiabatic compressibility (β), acoustic impedance (z) and free length (L_f) have been calculated at different aqueous concentration of rice protein. Solute- solvent interaction; stabilize the rice protein at low concentration. The order of solute – solvent interaction in aqueous solution was found 4%>8%>12%>16%>20% > 24%> and 28%.

Keywords: *Density (ρ), viscosity (η) Sound velocities (u) adiabatic compressibility (β), acoustic impedance (z) and free length (L_f), Rice protein.*

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I. INTRODUCTION

Starch is a polysaccharide of α-D- glucose monomers, found in food such as rice, potato, corn, barely. Starch is primary source of energy in human diet. In starch two component water soluble amylose and water insoluble amylopectin is present. Only α 1, 4 linkages are found in linear amylose while both α 1, 4 linkages and α 1, 6 linkages are found in amylopectin structure. The percentage of each component in starch is amylose 20–30% and amylopectin 70–80% respectively [1]. 12% water, 75% - 80% starch and only 7 % of protein is present in Rice grain [2]. 1 cup of white rice contains 45 grams of carbohydrates and only 4.3 grams of protein. This is a 9:1 ratio making it more carbohydrate and is used this way in most diets. Isolated rice protein (IRP) has two main protein fractions [3]:

1. Water and salt soluble: albumin (~5%), globulin (~12%),
2. Aqueous ethanol soluble glutelin (~80%) and prolamin (~3%).

Many studies have been done on molecular interactions and examined by means of ultrasonic velocity and viscometric methods [4-6]. Present study was to know the interaction of IRP in aqueous solution. For this purpose viscometric and ultrasonic studies have done at 287.79K.

1.1 Isolation of starch and Protein

Rice flour 160g dry base was mixed with aqueous sodium hydroxide having volume 800 ml and concentration 0.05 M. The content was stirred at 25 ^{0}C for 3h and allows settling for 24h. The supernent yellow color liquid containing protein was decanted in a separate volumetric flask. The fixed content was obtained after centrifugation and separation of solid starch. The aqueous alkaline solution containing rice protein obtained by removal of starch was taken for the experimental purpose. The solutions of different concentration were prepared by dilution with double distilled water (v/v). The solution was used for the dilution of required percentage in order to avoid the any biochemical reaction in solutions. The isolation of major constituent of starch present in rice has been isolated using the procedure used in the study and reported in literature [7].

1.2 Experimental Methods

The fractions of Rice protein isolate solutions are prepared by taking the volume percentage (v/v) from the stock solution. The percentage solution of RPI was 4%, 8%, 12%, 16%, 20%, 24% and 28%. The density was measured using the specific gravity bottle of 10 ml. Viscosity is determined by Ubblohde viscometer (Infusil India Pvt. Ltd. of number Z/1645. Ultrasonic interferometer (M-81 S Mittal Enterprises, New Delhi) is used to determine the velocity of liquids and liquid mixtures where the frequency kept constant (2 MHz).

Using values of density and ultrasonic velocity; values of viscosities and acoustical parameters are calculated. Following relations are used

$$\text{Adiabatic compressibility } \beta = \frac{1}{\rho u^2}$$

$$\text{Acoustic impedance } Z = u\rho$$

$$\text{Intermolecular Free length } L_f = k\sqrt{\beta}$$

Here, k is temperature dependent Jacobson constant. The value of Jacobson constant was (K = 93.875 + 0.375T) × 10^{-8} [8]

II. RESULT AND DISCUSSION

The data results obtained from density measurements, Viscometric studies and sound velocity measurements with their concentrations (4%, 8%, 12%, 16%, 20%, 24% and 28%) are listed in table 1. Acoustical parameters like adiabatic compressibility (β), acoustic impedance (z) and inter molecular free length (L_f) are also listed in table 1 and their corresponding graph are plotted against their respective concentration in Figure 1 to 6.

Table1. The values of density (ρ), relative viscosity (η), speed of sound (u) adiabatic compressibility (β), acoustic impedance (Z) and intermolecular free length (L_f) for the different concentration (v/v) of brown rice protein.

Conc. V%	ρ (Kg/ml)	η_r	U m/s	β × 10^{-10} (m^2/N)	Z × 10^6 (Kgm^{-2}s^{-1})	L_f × 10^{-5} (m)
4	995.3	0.3347	1528.0	4.303	1.520	2.074
8	996.1	0.3385	1510.0	4.402	1.504	2.098
12	997.2	0.3354	1500.0	4.456	1.495	2.110
16	998.0	0.3392	1490.0	4.513	1.487	2.124
20	998.9	0.3427	1480.0	4.570	1.478	2.137
24	999.6	0.3397	1472.0	4.616	1.471	2.148
28	100.07	0.3436	1466.0	4.649	1.467	2.156

The Linear manner of density in g/ml with solute concentration was reported by Kirinceic and Klofutar [9]. The density is a measure of solvent – solvent and solute – solvent interactions. Increase in density is with the concentration indicates solute – solvent interactions. Shrinking of volume occurs with increase in density. An Increase in density is due to increases in the size of solute molecules which cannot interact with solvent molecules strongly hence there will be decreases in solute – solvent interaction at higher concentration. In this study the density data is increased from 0.9953 g/ml to 1.0007 g/ml which confirms isolated rice protein interacts less with water molecules at higher concentration due to chain lengthening of isolated rice protein.

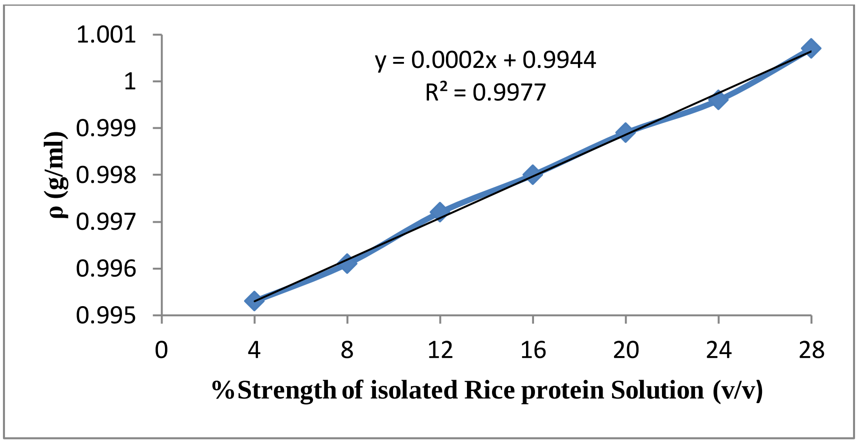

Figure1: Density (ρ) in g/ml versus % strength of isolated Rice protein solution (v/v)

The oil as lubricant has a high viscosity coefficient and may use in various cleaning process [10]. Thus, viscosity is the key physicochemical property of any liquid. Viscosity curves are one of the most useful tools to know the physicochemical properties of solutions. Strong solute-solvent attractions equate to greater solubility while weak solute-solvent attractions equate to lesser solubility. Figure 2 shows variation of viscosity with % strength of isolated rice protein in nonlinear way. Figure 2 shows the peak viscosity, trough viscosity, and final viscosity for each % strength of isolated rice protein. As the concentration of water was decreased 4%

to 28%, the peak height of the waxy varieties increased linearly, but that of the non-waxy varieties increased exponentially [11].

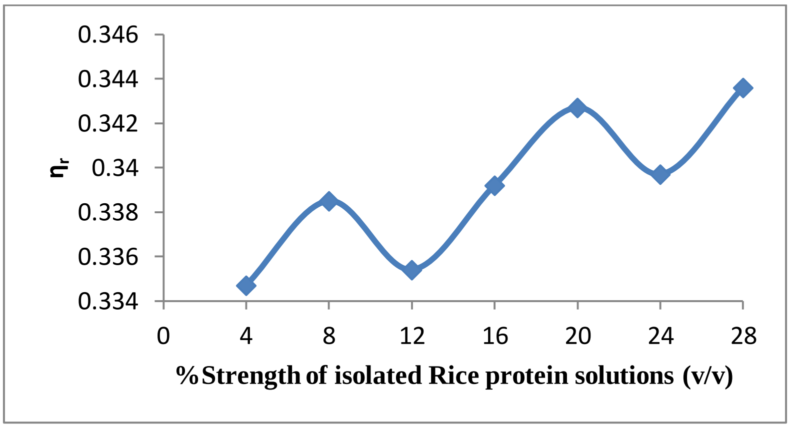

Figure 2: Relative viscosities (η) versus % strength of isolated Rice protein solution (v/v)

Speed of sound at different % strength of IRP decreases linearly with regression value $R^2 = 0.98$ in figure 3. The linear plot suggests there is strong solute –solvent interactions in the aqueous solutions of an IRP. As the length of globular protein increases, their solubility in water decreases [12-13]. In this study the strength of solute – solvent interaction is decreased with increase in concentration this is due to the fact that on increasing IRP concentration protein become bulky and less soluble in water. At lower concentration of solute in aqueous solution IRP forms hydrogen bond with water molecules i.e., lower concentration of IRP has greater structure maker property than higher concentration. Protein molecules have tendency to attract solvent molecules due to weak van der Waal force and hydrogen bonding. The molecules present in the solution are disturbed on passing sound waves but for attaining equilibrium molecules regain their positions due to elastic nature. This compression occurs here only at lower concentration value of IRP. This aggregation of solute molecules around solvent molecules supports powerful solute-solvent interactions.

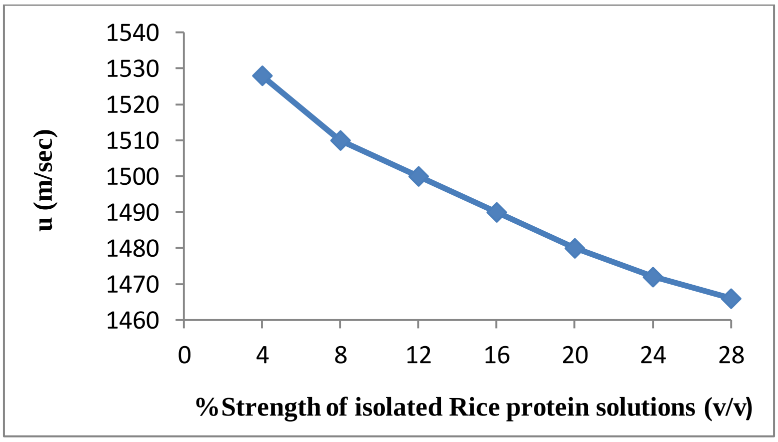

Figure 3: Sound velocity (η) versus % strength of isolated Rice protein solution (v/v)

Sound velocity of a solution depends on the intermolecular free length. The model of sound propagation was given by Kincaid and Eyring [14]. Sound velocity decreases with increases of intermolecular path length (L_f) as in figure 4. Greater the intermolecular path length, sound wave pass more easily to the solution and aggregation of solute molecules become fast. Adiabatic compressibility increased linearly with decreases in sound velocity i.e., there is compression occurs at higher concentration which also supports structure making property of IRP at low concentration.

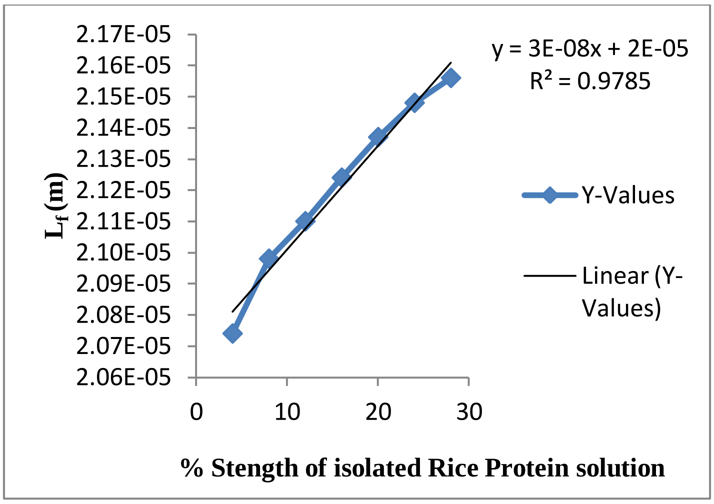

Figure 4: Free length (L_f) versus % strength of isolated Rice protein solution (v/v)

Adiabatic compressibility is the reciprocal of bulk modulas; it is the property of the substances capable of bringing reduction in volume by application of pressure. The plot shown in figure 5 indicates that adiabatic compressibility increases with increase in concentration of IRP. Increase in adiabatic compressibility indicates that the medium become less compressible and it also suggest that the interactions of proteins molecules around water molecules rather than water to protein molecules.

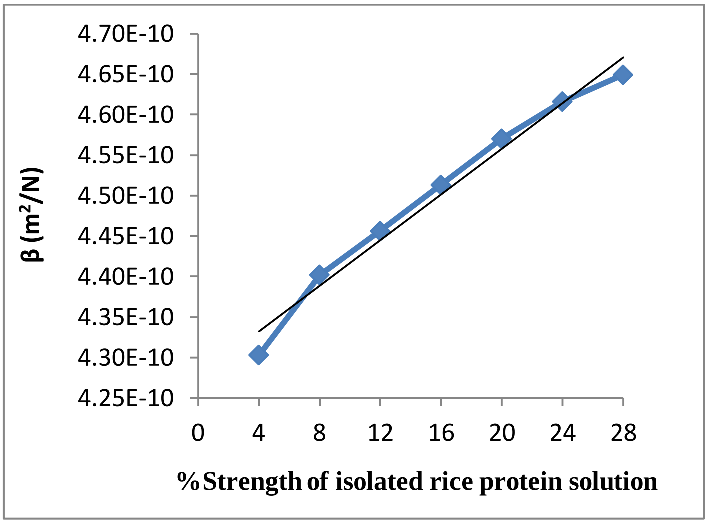

Figure 5: Adiabatic Compressibility (β) versus % strength of isolated Rice protein solution (v/v)

Acoustic impedance is the resistance to the propagation of ultrasound waves through solvent containing solute particles. It is the product of the density and speed of sound in solutions. In figure 6 a decrement in the value of acoustic impedance also supports a resistant in solution due to solute particles on increasing the concentration of IPR solution.

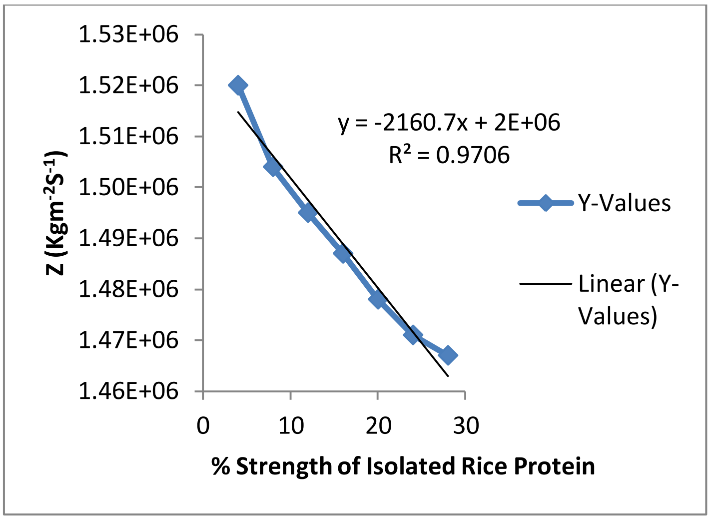

Figure 6: Acoustic Impedance (z) versus % strength of isolated Rice protein solution (v/v)

III. CONCLUSION

It was observed that density, viscosity and ultrasonic study favors bonding in isolated rice protein at lower concentration rather than higher in which aggregation of solute particles arises about solvents molecules. This study showed that isolated rice protein (IRP) was structure maker only at lower concentration. At higher concentration due to chain lengthening of rice protein or bulkiness solute – solvent interaction is decreased to appreciable extent. Other acoustical parameters such as adiabatic compressibility (β), acoustic impedance (z) and intermolecular free length also supports the aggregation of protein molecules about water molecules. Solute (Protein) – Solvent (Water) interaction is greater in 4% then followed by 8%, 12%, 16%, 20%, 24 % and 28% respectively.

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