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Study of Viscoelastic Parameters of Desi Chickpea Flour

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Abstract

Rheological properties of desi chickpea flour (besan) obtained using a parallel plate viscometer have been studied. The rheological test were performed by using two plates parallel to each other with diameter of each plate of 20 mm diameter with a gap of 500 µm was used for the fundamental rheological tests. Dough prepared by mixing equal amount of flour and water was used for the test. Shear stress and shear rate data showed that dough was pseudoplastic and have yield stress. Bingham model was applied to the shear rate shear stress data to know the yield stress and the viscosity of the samples. Oscillation test gave information about the change in viscoelastic nature of the dough samples with increasing frequency. It was seen that the sample behaves as a viscoelastic fluid. The elastic modulus over dominates the viscous modulus after crossover frequency. Crossover frequency helps in understanding the deformation in structure of the samples with time. The study helps in understanding the rheological parameters of the chickpea flour for food processing applications.

Keywords: desi chickpea flour, fundamental rheology, creep recovery, viscoelastic

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INTRODUCTION

The nutritional quality of pulses, make it the most important crops in the world as being a good surces of carbohydrates, vitamins, minerals and protein [1]. Consumption of pulses also help the diabetic people to maintain their health [2], cancer prevention and providing protection against cardiovascular disease**s,** type II diabetes, and obesity [3-5], because of their fiber content [6]. Chickpea is unique among the grain legumes because of different food products made from it in different parts of the world. The protein of chickpea is in the range 20.6-26.7, carbohydrate in 60.9-66.3 and crude fat content as 0.53-1.21 % [7]. Almost 70% of the world's production and consumption is in India, it is also important in other countries of Africa, Europe, Asia and the Americas. Chickpea seeds consumption can be done as whole or decorticated after cooking and processing in different ways. Desi chickpea flour called besan is also used in many dishes and also as supplement [8]. They are also consumed in the forms such as bread pasta, cakes, cookies and crackers due its good nutritional properties [9-10].

Rheology is the study of the deformation and flow of matter [11]. A lot of research is conducted to understand the rheology of various types of food such as food powder (Grabowski et al. 2008), liquid food [12], gels [13], emulsions [14]. Rheological behaviour of chickpea, give information about its structure composition and viscoelastic nature [15].

The objectives of this work are to study the viscoelastic properties of desi chickpea flour to understand its viscoelastic nature.

MATERIAL AND METHODS

Sample Preparation

Besan samples of different brands were purchased locally. Dough sample was prepared according to the rheological method explained for wheat [16].

Rheological test

Viscometery test is used to find the variation of viscosity with varying shear rate and shear stress. This helps in determining the nature of the samples .i.e. newtonian or non newtonian.

Dough was kept in between the parallel plates of Malvern CVO Bohlin rheometer with a gap of 500 µm. Shear rate was varied from 0.1-40 per s and change in viscostiy and shear stress was observed using the Bohlin software. In another test shear stress was varied from 0.3 -80

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Pa and variation in viscosity and shear rate were observed. Herschel Bulkley and Power law was used to find the nature of the besan dough samples.

Herschel Bulkley model $\sigma = \sigma_0 + k\dot{\gamma}^n$ (1)

Power Law $\sigma = \eta\dot{\gamma}^n$ (2)

Where σ is shear stress, σ_0 yield stress, $\dot{\gamma}$ shear rate, k is consistency index, η is viscosity and n is the flow index gives an idea of the viscosity of the fluid and k is the consistency index parameter. If n<1 it is a shear thinning fluid and for n>1 shear thickening fluid. If n = 1 and σ_0 = 0 the fluid is Newtonian.

Oscillation test consists of amplitude sweep followed by frequency sweep. Amplitude test is used to find the linear viscoelastic region (LVR) of the sample. This is the region where the viscous and elastic modulus of the samples remain same with the change in shear stress/shear rate applied. The frequency sweep test is run in the LVR and the change in viscous and elastic modulus is observed with the change in stress applied. This helps in determining the change of a sample from viscoelastic nature to elastovisous or vice versa.

Amplitude sweep test was performed on the samples to find the LVR and then the frequency weep was run using the selected parameters. Stress was kept constant at 30 Pa, frequency for the test was varied from 0.1 to 30 Hz. Changes in viscous modulus (G”) and elastic modulus (G’) with increase in frequency were observed. The change in phase angle with frequency was also observed.

Creep and recovery test is used to find the stress relaxation behaviour of the sample. Sample is subjected to a fixed stress for a given time and then the stress applied is released and the change in the behaviour of the sample is observed.

A constant stress of 15 Pa was applied on the sample. Maximum deformation was observed when the applied stress was in the above range. After 100 sec stress was removed instantly and recovery phase was observed, stored energy was used to restore the actual structure.

RESULTS AND DISCUSSION

Shear rate ramp-viscosity curves of besan dough samples are shown in Figure 1. The curves show that the samples behaved like a non Newtonian fluid with a shear thinning behavior. Increase in shear rate decreases the viscosity of the besan dough samples. The curve can be divided into two zones depending on the shear rate magnitude at starting shear rates, the decrease in viscosity is sharp, whereas at higher shear rate, there is low change in viscosity of

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the dough samples. Shear rate –shear stress curves (Figure 2) also show that the samples behaved like pseudoplastic fluids. This behavior is observed due to breakdown in the structure with increasing shear rate for the besan dough samples.

Viscometery Rheological models

The Herschel Bulkley model (Equation 1) correlated shear rate and stress with r^2 value greater than 0.99. Value of flow index is less than 1 for all the besan dough samples showing its pseudoplastic behavior Table 3.1 [11]. With 1:1 ratio of flour and water besan dough samples, the flow behavior index (n) of the Herschel Bulkley model varied between 0.35-0.70, showing that the fluid is of shear thinning characteristics. Shear rate range for all the samples was same 0.1-40 per s. The index of consistency of all the samples ranged from 31.53-121.7. Consistency index of the sample gives information about viscosity of the samples. As the flow index is less than 1, it indicates that the sample is having a shear thinning behaviour. From Equation (3) if the flow index is equal to 1, then the consistency index is equal to the viscosity of the sample. If $n < 1$ then k is greater than the viscosity of the samples and if $n > 1$, k is less than the viscosity of the samples. The Table 1 shows that the $n < 1$, thus the viscosity of the samples are less than the calculated values of consistency index. The power law model parameters shown in Table 2 also shows the shear thinning behaviour of the samples, due to the value of flow index between 0.47 – 0.69. The power law model also fits well for the samples with r^2 values between 0.993-0.999.

Thus the power law and Hershley belkley model parameters show that both model can be used to characterize the nature of besan dough samples.

Frequency sweep results

To characterize the besan dough sample, the frequency dependent nature of the besan samples was examined using oscillatory measurements with application of constant stress of 30 Pa. The parameters for the frequency sweep are measured from the linear viscoelastic region (LVR) obtained from amplitude sweep test. Relations in G', G" and tan δ with frequency for the besan dough samples are shown in Figure 3. The data for the besan samples indicate that the oscillation frequency from 0.1 – 30 Hz, causes an increase in the values of viscous modulus (G") and elastic modulus (G'), whereas value of $\tan\delta$, ratio of $G'/_{G''}$, gently decreases (Figure 3). With further increase of oscillation frequency from 0.1 to approximately 6 Hz it was observed that the elastic modulus over dominates the viscous modulus of the

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samples, conversion of the viscoelastic solid to elastoviscous liquid, confirming their solid elastic nature. Similar frequency dependence was noted by different researchers for chickpea-wheat flour blends [17], cookie dough's [18].

It is observed that the elastic and viscous modulus increases with increase in frequency of oscillation applied on the sample. The increased values of modulii shows that the capacity of the dough to store its energy on the application of external forces (G') and the energy dissipated during by the dough increases with increase in the oscillation frequency. Energy dissipation occurs due to friction that occurs during the slippage of one element of dough past another. The storage of energy is due to reversible rearrangements within each element of the dough building the structure [19].

Creep and Recovery Tests

Creep recovery of all the samples is shown in Figure 4. Instantaneously recovered elastic strain after the removal of load was small for the chickpea dough. Recovery curves shows low flowability of the besan dough samples as the recovery compliance is very small. It was observed that Maximum creep compliance for S1 and S3 were 0.00754 and 0.008165 respectively. The low values of creep compliance showed that the besan dough have very low elasticity. Recovery compliance values for besan dough for samples S1 and S3 were 0.000715 and 0.0024, which are very less showing no or very less recovery of the besan dough samples. The creep recovery parameters show that the besan dough is rigid in nature.

CONCLUSION

In this chapter the rheological properties of besan dough and their viscoelastic behaviors were discussed. The results indicate that the besan dough behaves as a non Newtonian fluid with shear thinning behavior. The value of elastic and viscous modulus increased with an increase in oscillation frequency. The oscillation results indicate that rheological properties of besan dough have elastic behaviour. Viscoelsatic nature of the dough changes to elastoviscous nature with increasing frequency.

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Table 1 Herschel Bulkley model parameters for the non Newtonian besan dough samples.

Sample	r^2 (correlation coefficient)	σ_0 (yield stress)	k (consistency index)	n (flow index)
S 1	0.998	0	121.7	0.3542
S 2	0.996	0	47.9	0.5186
S 3	0.9994	1.545	58.99	0.5052
S 4	0.9998	0	28.96	0.6294

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Table 2 Power law model parameters for the besan dough samples

Sample	r^2 (correlation coefficient)	η (viscosity)	*n* (flow index)
S 1	0.993	50.23	0.56
S 2	0.998	30.63	0.6364
S 3	0.9992	60.76	0.4754
S 4	0.9975	22.62	0.6947

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FIGURE CAPTIONS

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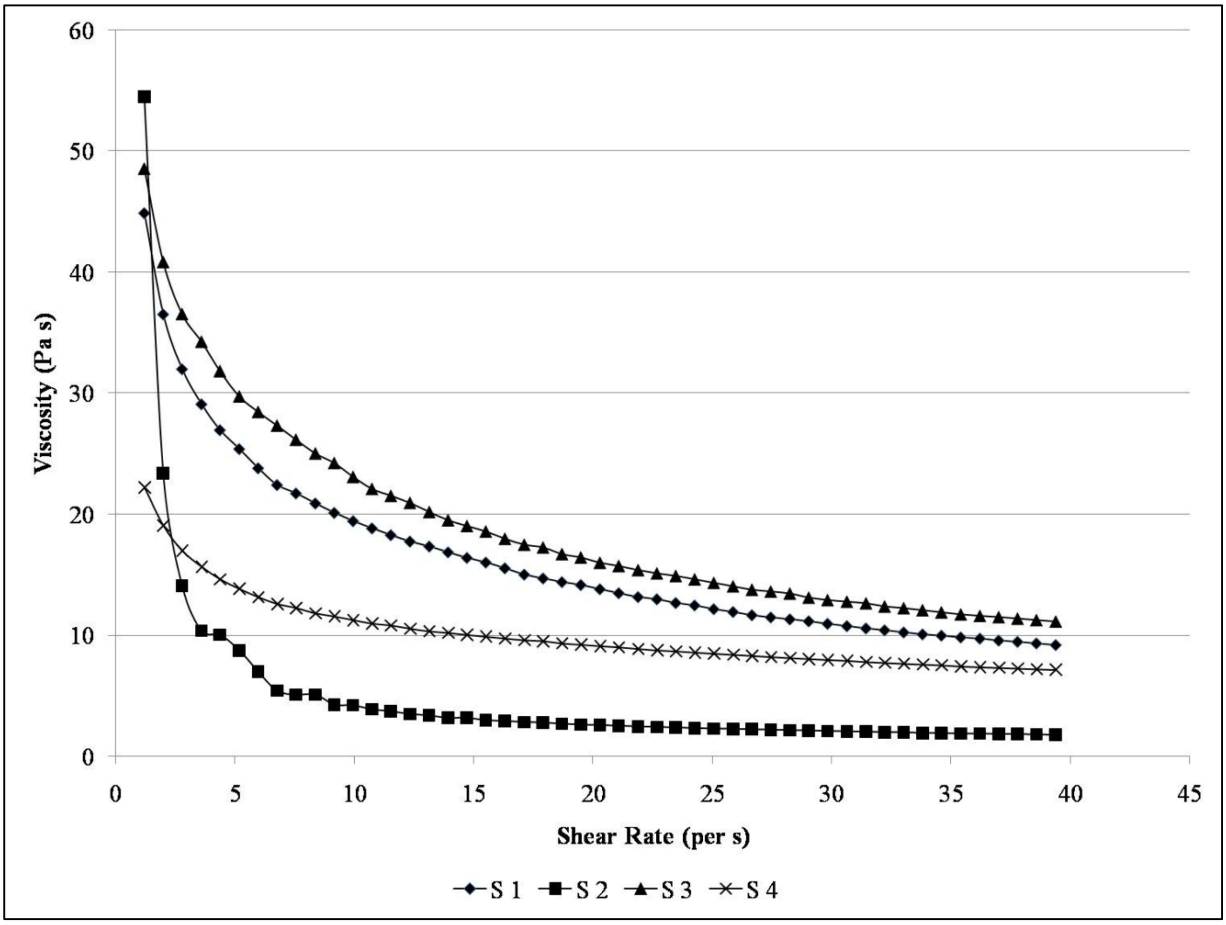

Figure 1

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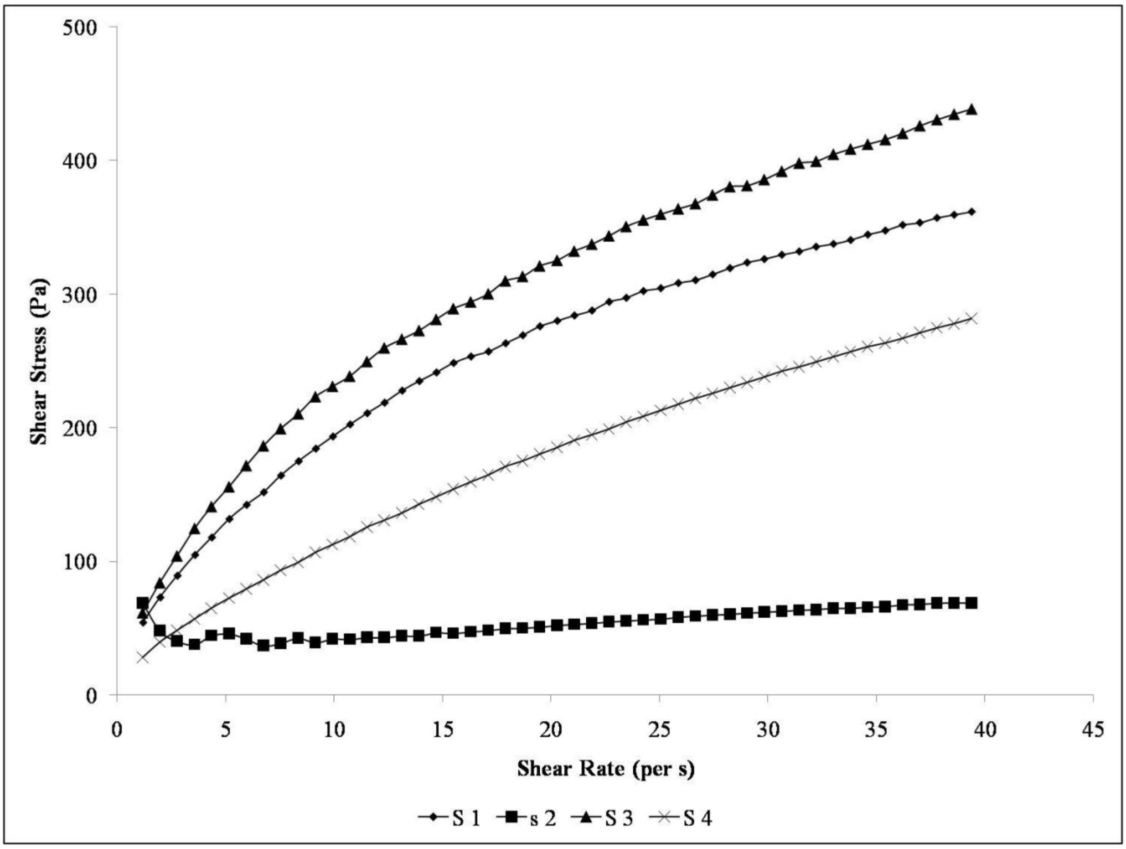

Figure 2

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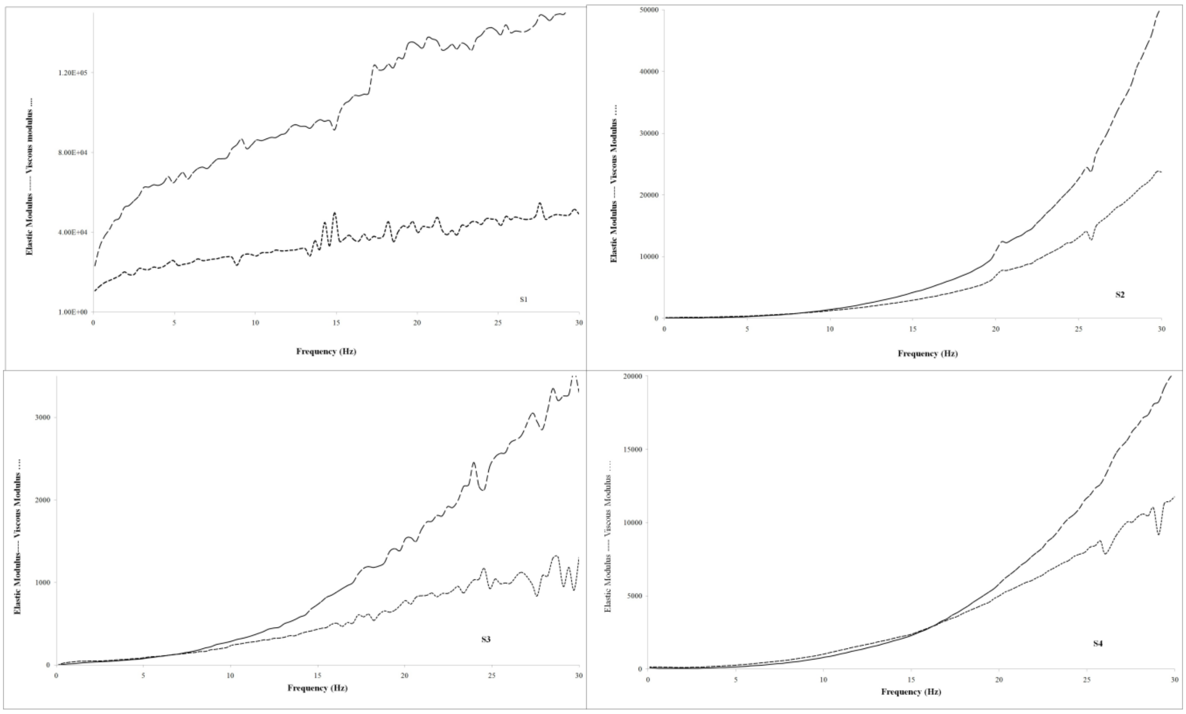

Figure 3

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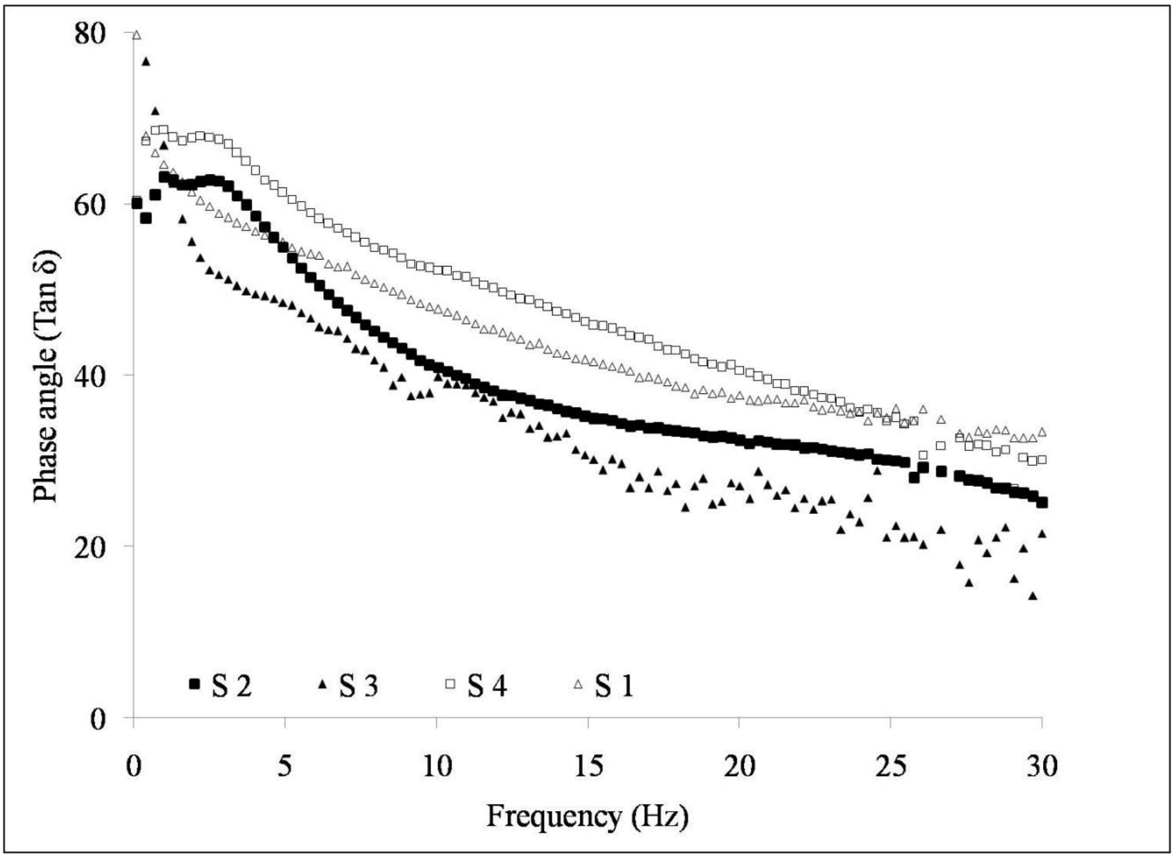

Figure 4

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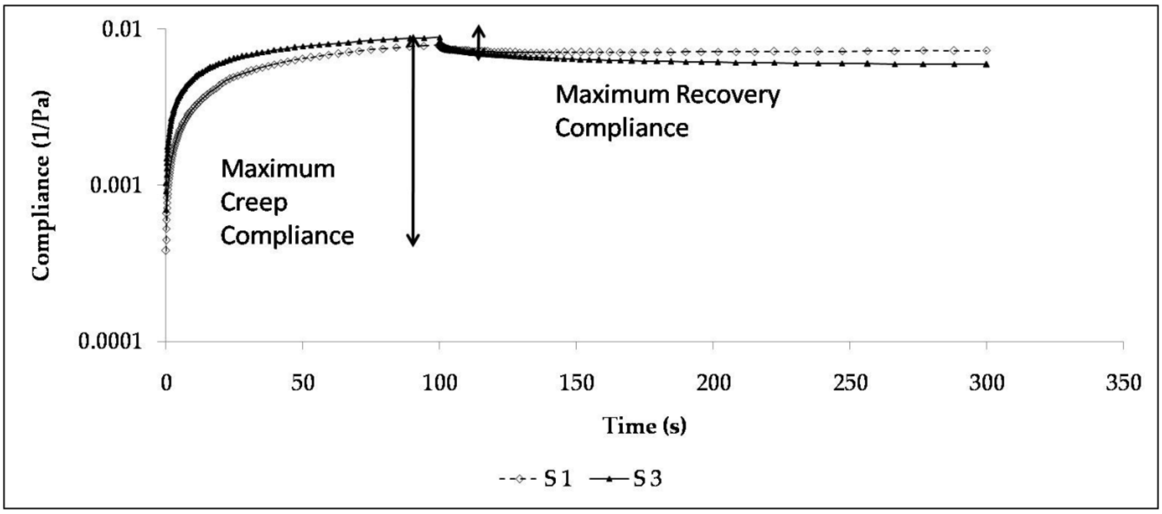

Figure 5