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Miscibility study of poly acrylamide (PAM) and Acacia Senegal (gum arabic) blends

David Ebuka Arthur[a]*, Augustina Aroh Oyibo[b], Samuel N Adawara[b], Samuel Hassan[c], Emmanuel Uwaiya[c]

[a]*Department of Chemistry, Baze University Abuja, Nigeria*
[b]*Department of Chemistry, Ahmadu Bello University Zaria, Nigeria*
[c] *Nigerian Institute of Leather and Science Technology Samaru, Zaria*

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ABSTRACT

The work entails the viscometric study of a common plant gum found in Nigeria (*Acacia Senegal*) blended with polyacrylamide (PAM). The gum was purified after collected and mixed in specific ratios of 10:90, 30:70, 50:50, 70:30 and 90:10 with PAM, before they were subjected to rheological study. The intrinsic, relative and specific viscosity for the bends were determined and presented in the research work. The plots of the relative viscosity against concentration of the gums at different temperature vary significantly at higher concentration, while the viscosity for gum Arabic/PAM (90:10) showed the most distinct variation between different temperatures. PAM was found to be more viscose than gum Arabic at both temperatures, while the viscosity index such as intrinsic, specific and relative viscosity for the synergistic combination between the polymers were found to decrease as we increased the composition of gum Arabic within the blend.

1. Introduction

Polymer blend may be defined as a combination of two or more polymers to produce a single material. Polymers are blended in order to achieve properties that cannot be achieved from a homo polymer [1, 2].

Viscometric method of studying compatibility is achieved much attention in the recent years because the method provides simple and an accurate means of studying polymer blends [3, 4]. In this study the use of viscometric method is highlighted. More importantly, the viscometric method was choosen because it is simple and required no expensive equipment's, yet offer the compatibility of the polymer blends constituents into compatible or incompatible.

However, there is a need to find simple and quicker methods for determining compatibility [5, 6]. Several blending procedures are available, and method commonly employed are; melting method, dry method and solution method of blending [7]. Polyacrylamide formed from acrylamide subunits. It can be synthesis by a simple linear-chain structure or cross- inked, typically using N, N'-methylene biacyrlamide [8-10].

Nigeria produces different grades of exudates and is ranked as second largest world producer after Sudan, together they produce about 45,000 tons of gum Arabic to the market each year [11]. Gary and Ryan (2002) reported that the trees grow more in Borno, Yobe, Sokoto, and Bauchi states of Nigeria. The trees are used as potent weapon in the fight against land desertification and soil degradation in sahelian belt of the country without industrial uses [12-14].

The aim of the above work is to investigate compatibility of gum Arabic with Polyacrylamide blend so as to serve the work as a study for improving properties of the blend and compare this property with that of Individual polymer present in the blend.

Viscometric method is based on the study of interaction in dilute solution of two polymers in common solvent [15].

2. Methodology

2.1. Purification of Gum Arabic

The presence of impurities in the gum Arabic reduces the quality of the gum, as such; the need to remove these impurities arises in order to improve the gum Arabic quality to an acceptable standard [16]. The steps

* Corresponding author. e-mail: eadavid@abu.edu

involved in the purification include;

2.1.1. Sample collection

The raw Gum Arabic sample was purchased from Sabon Gari Market, Zaria, Kaduna State. The sample is relatively pure, however impurities such as pieces' wood and broken leaves were carefully removed by hand and then air dried until it became sufficiently brittle. Then the raw Gum Arabic was reduced to smaller particle size using mortar and pistel to fine powder.

2.1.2. Gum Arabic solution preparation

500g of gum Arabic powder was dissolved in 300ml of distilled water and allowed to stand for 48 hours with intermittent stirring to ensure complete dissolution of the gum. The gum mucilage was then strained through a filter cloth into a basin to remove impurities in order to obtain particle-free slurry which was allowed to sediment. Thereafter, the gum supernatant was precipitated from the slurry by addition of 550 ml of 96% ethanol.

2.1.3 Filtration process

The precipitated Gum Arabic prepared, was poured into the Buchner funnel contain filter paper and this was done in such a way that the Buchner funnel was filled to the top (brim) in order to exert enough pressure to push down the solution through the Buchner funnel. The solution that passed through was then collected in a Buchner flask and discarded. The purified residue was collected and put into basin. Finally, the residue was air dried and crushed as refined Gum Arabic ready for the work.

2.2. Preparation of Polymer Blend

The blends were prepared by solution. Different blend composition of PAM/GUM ARABIC, with total composition of 100% was prepared in the fallowing composition (%) of gum Arabic/PAM as: 10/90, 30/70, 50/50, 70/30, 90/20, 0/100, 100/0. Each of the composition above was later weight as: 0.1g, 0.5g, 1.0g, 1.5g, 2.0g, 2.5g, and 3.0g and dissolved in 1000ml of distilled water as a different concentration.

2.3. Determination of Viscosity

About 10ml of distilled water was pipetted into a Ostwald viscometer through a large opening. The viscometer was mounted to a retort stand and inserted into suitable temperature control water bath in a vertical position. And the temperatures were kept at $\pm 25^0$C, and the viscometer is allowed to stay for about 30sec to attained equilibrium [17]. The solvent was then suck using hand pump to upper level and then allowed to drain to the lower level. The times of flow from upper to lower level was recorded by starting a stopwatch immediately and stop as it reached the lower level. Two times of the above procedure was repeated and the averages were computed as flow time (viscosity) of the solvent. The above procedure was repeated for each concentration of the above composition.

2.4. Determination of Relative and specific viscosity

The intrinsic viscosity $[\eta]$ is a measure of the hydrodynamic volume occupied by a macromolecule, which is closely related to the size and conformation of the macromolecular chains in a particular solvent [18]. The intrinsic viscosity $[\eta]$ is determined experimentally from measurements of the viscosity of very-low-concentration (C) solutions. Denoting solution and solvent viscosity as, respectively, η_{solution} and η_{solvent}, $[\eta]$ is defined by the following relationships:

Relative viscosity: $\eta_{rel} = \frac{\eta_{solution}}{\eta_{solvent}}$ …(1)

Specific viscosity: $\eta_{sp} = \eta_{rel} - 1$ …..(2)

Intrinsic viscosity: $[\eta] = \lim_{C \to 0} \frac{\eta_{sp}}{C}$ ….(3)

The intrinsic viscosity can be obtained by measuring specific viscosities at different concentrations at the same shear-rate, and extrapolating the course of specific viscosity to infinite dilution [19]. The intrinsic viscosity $[\eta]$ is, therefore, obtained by extrapolating data to zero concentration by using a linear regression, which will be called the graphic double-extrapolation procedure (GDEP) in this study. McMillan (1974) showed that $\frac{\eta_{sp}}{C}$ also called reduced viscosity, could be written in the form of a Huggins equation (Huggins, 1942)

$$\frac{\eta_{sp}}{C} = [\eta] + K^l[\eta]^2 C \quad \text{…….(4)}$$

where k^l is the Huggins constant. The determination of the intrinsic viscosity is, therefore, the extrapolation of reduced viscosity to the value at zero solute concentration. The extrapolations are usually done in very dilute regimes ($C \ll C^*$) with relative viscosity values between 1.2 and 2.0, the corresponding specific viscosities being between 0.2 and 1.0 [20, 21]. C* is defined as the overlap concentration, the transition from the dilute to the semi-dilute region which mark the onset of polymer entanglement [22]. In the present work, gum solutions were therefore diluted to be within the described range. In addition, McMillan (1974) reported that the intrinsic viscosity could be obtained from the Kraemer equation [23] by extrapolation to zero concentration (C)

$$\frac{\ln \eta_{rel}}{C} = [\eta] + k^{ll}[\eta]^2 C \quad \text{…….. (5)}$$

where k^{ll} is the Kraemer constant. For very dilute solutions, however, Eq. (5) can be shortened by retaining only the first-order term, and $[\eta]$ can be

determined from the slope of a plot of C against ln η_{rel} [24]. McMillan (1974) showed that methods of determination of the intrinsic viscosity that were based on slopes of plots had higher correlation coefficients and lower standard errors, compared with those based on intercepts of plots. On the basis of such findings, Tanglertpaibul and Rao (1987) [25] used the following equations to obtain the intrinsic viscosity of tomato serum:

$$\eta_{rel} = 1 + [\eta]C \quad \text{.....(6)}$$

The intrinsic viscosity $[\eta]$ is the slope obtained by plotting

$$\eta_{rel} \; vs. C$$

$$\eta_{rel} = e^{[\eta]c} \quad (7)$$

The intrinsic viscosity $[\eta]$ is the slope obtained by plotting

$$\ln \eta_{rel} \text{ vs. C}$$

$$\eta_{rel} = \frac{1}{1-[\eta]c} \text{.....(8)}$$

The intrinsic viscosity is the slope obtained by plotting

$$1 - \frac{1}{\eta_{rel}} \text{ vs. C.}$$

The intrinsic viscosity $[\eta]$ was estimated based on the slope of η_{sp} vs. C for polyelectrolytes, as suggested by Chou and Kokini (1987) [26]; this is similar to the method discussed in Eq. (6). Chou and Kokini (1987) reported that when there is essentially no molecular interaction, as in dilute solutions, the second term of the Huggins equation (Eq. 4) is negligible, and a plot of η_{sp} against concentration is linear. In this study, the intrinsic viscosity in the dilute domain was estimated on the basis of Eqs. (5), (6), (7), and (8), and the four methods were statistically compared for a better fit.

The intrinsic viscosity of the gum samples was determined in distilled water. The gum solutions were prepared by dispersing 50 mg of each of the gum sample (db, dry basis) separately in 100 ml of the distilled water at room temperature and mixing with magnetic stirring overnight. 2 ml of solution was transferred into an Ostwald viscometer which was immersed in a precision water bath to maintain the temperature at 25.0±0.1 °C and after equilibration for 10 minutes, the flow time was determined between the two etched marks. Serial dilution was performed in situ and three readings were taken for each dilution and averaged. The relative viscosity (η_{rel}) would be calculated using the equation

$$\eta_{rel} = \frac{t - t_0}{t_0}$$

Where t is the flow time of gum solution in seconds, t_0 is the flow time of solvent (water) in seconds.

3. Results and Discussions

3.1 Relative viscosity against concentration was plotted over an extended range of the blend solution.

Flow time of water (solvent) = 9.5sec

Thermodynamic and transport properties of polymer blend, help in understanding the nature of molecular interaction taking place in solution, this further help in improving on the quality grade of polymer blend both in food and pharmaceutical industries.

Fig 1 and 2 show a plot of relative viscosity Vs. concentration at different temperature (i.e. 25^0C and 50^0C). it was observed from that fig 1 and 2, that the plot is linear at both temperatures of 25^0C and at that of 50^0C, hence, indicate compatible polymer blend.

TABLE 1: Viscosity measurement of gum Arabic/PAM blend at 25^0C

Concentration g/ml	Composition (10/90)%	Intrinsic Viscosity (Ns/m^2)	Relative viscosity (Ns/m^2)	Specific viscosity (Ns/m^2)
0.1	G.A/PAM	17	2.7	1.7
0.5	G.A/PAM	10.2	6.1	5.1
1.0	G.A/PAM	6.5	7.5	6.5
1.5	G.A/PAM	7.1	11.7	10.7
2.0	G.A/PAM	6.0	12.9	11.9
2.5	G.A/PAM	8.1	21.1	20.1
3.0	G.A/PAM	9.6	29.7	28.7

It was also observed the same situation from fig 3 and 4, but in fig.3 at a temperature of 25^0C there is small decrease in viscosity at a concentration of 2.5 Ns/m^2-3.0 Ns/m^2.

TABLE 2 Viscosity measurement of gum Arabic/PAM blend at 25^0C

Concentration g/ml	Composition (30/70)%	Intrinsic Viscosity (Ns/m^2)	Relative viscosity (Ns/m^2)	Specific viscosity (Ns/m^2)
0.1	G.A/PAM	17.0	2.7	1.7
0.5	G.A/PAM	11.0	6.5	5.5
1.0	G.A/PAM	6.0	7.0	6.0
1.5	G.A/PAM	5.8	9.7	8.7
2.0	G.A/PAM	7.5	16.0	15.0
2.5	G.A/PAM	9.3	24.3	23.3
3.0	G.A/PAM	9.2	28.5	27.5

TABLE 3 Viscosity measurement of gum Arabic/PAM blend at 25^0C

Concentration g/ml	Composition (50/50)%	Intrinsic Viscosity (Ns/m^2)	Relative viscosity (Ns/m^2)	Specific viscosity (Ns/m^2)
0.1	G.A/PAM	-2.0	0.8	-0.2
0.5	G.A/PAM	4.8	3.4	2.4
1.0	G.A/PAM	3.9	4.9	3.9
1.5	G.A/PAM	4.4	7.6	6.6
2.0	G.A/PAM	2.2	9.8	8.8
2.5	G.A/PAM	7.1	18.7	17.7
3.0	G.A/PAM	8.8	27.5	26.5

TABLE 4: Viscosity measurement of gum Arabic/PAM blend at 25^0C

Concentration g/ml	Composition (70/30)%	Intrinsic Viscosity (Ns/m^2)	Relative viscosity (Ns/m^2)	Specific viscosity (Ns/m^2)
0.1	G.A/PAM	-3.0	0.7	-0.3
0.5	G.A/PAM	4.4	3.2	2.2
1.0	G.A/PAM	3.1	4.1	3.1
1.5	G.A/PAM	4.0	7.0	6.0
2.0	G.A/PAM	4.3	9.5	8.5
2.5	G.A/PAM	6.1	16.1	15.1
3.0	G.A/PAM	6.4	20.2	19.2

TABLE 5: Viscosity measurement of gum Arabic/PAM blend at 25^0C

Concentration g/ml	Composition (90/10)%	Intrinsic Viscosity (Ns/m^2)	Relative viscosity (Ns/m^2)	Specific viscosity (Ns/m^2)
0.1	G.A/PAM	-6.0	0.4	-0.6
0.5	G.A/PAM	2.0	2.0	1.0
1.0	G.A/PAM	1.8	2.8	1.8
1.5	G.A/PAM	3.3	6.0	5.0
2.0	G.A/PAM	3.3	7.5	6.5
2.5	G.A/PAM	5.2	13.9	12.9
3.0	G.A/PAM	9.6	29.7	28.7

TABLE 6: Viscosity measurement of 100% gum Arabic at 25^0C

Concentration g/ml	Composition 100 %	Intrinsic Viscosity (Ns/m^2)	Relative viscosity (Ns/m^2)	Specific viscosity (Ns/m^2)
0.1	G.A/PAM	10	0.03	-1.0
0.5	G.A/PAM	-1.2	0.4	-0.6
1.0	G.A/PAM	-0.6	0.4	-0.6
1.5	G.A/PAM	0.2	0.7	0.3
2.0	G.A/PAM	0.1	1.1	0.1
2.5	G.A/PAM	0.2	1.4	0.4
3.0	G.A/PAM	0.6	2.8	1.8

TABLE 7: Viscosity measurement of 100% PAM at 25^0C

Concentration g/ml	Composition 100%	Intrinsic Viscosity (Ns/m^2)	Relative viscosity (Ns/m^2)	Specific viscosity (Ns/m^2)
0.1	G.A/PAM	18.0	2.8	1.8
0.5	G.A/PAM	16.6	9.3	8.3
1.0	G.A/PAM	15.0	16.0	15.0
1.5	G.A/PAM	15.7	24.6	23.6
2.0	G.A/PAM	13.5	28.0	27.0
2.5	G.A/PAM	12.7	32.7	31.7
3.0	G.A/PAM	13.4	41.1	40.1

TABLE 8: Viscosity measurement of gum Arabic/PAM blend at 50^0C

Concentration g/ml	Composition (10/90)%	Intrinsic Viscosity (Ns/m^2)	Relative viscosity (Ns/m^2)	Specific viscosity (Ns/m^2)
0.1	G.A/PAM	1.0	1.1	0.1
0.5	G.A/PAM	5.0	3.5	2.5
1.0	G.A/PAM	5.3	6.3	5.3
1.5	G.A/PAM	5.5	9.3	8.3
2.0	G.A/PAM	4.4	9.7	8.7
2.5	G.A/PAM	4.8	12.9	11.9
3.0	G.A/PAM	3.7	12.0	11.0

TABLE 9: Viscosity measurement of gum Arabic/PAM blend at 50^0C

Concentration g/ml	Composition (30/70)%	Intrinsic Viscosity (Ns/m^2)	Relative viscosity (Ns/m^2)	Specific viscosity (Ns/m^2)
0.1	G.A/PAM	-2.0	0.8	-0.2
0.5	G.A/PAM	4.4	3.2	2.2
1.0	G.A/PAM	2.4	3.4	2.4
1.5	G.A/PAM	3.1	5.6	4.6
2.0	G.A/PAM	4.0	8.9	7.9
2.5	G.A/PAM	3.5	9.8	8.8
3.0	G.A/PAM	2.8	9.5	8.5

TABLE 10: Viscosity measurement of gum Arabic/PAM blend at 50^0C

Concentration g/ml	Composition (50/50)%	Intrinsic Viscosity (Ns/m^2)	Relative viscosity (Ns/m^2)	Specific viscosity (Ns/m^2)
0.1	G.A/PAM	0.0	1.0	0.0
0.5	G.A/PAM	1.0	1.5	0.5
1.0	G.A/PAM	2.0	3.0	2.0
1.5	G.A/PAM	2.1	4.1	3.1
2.0	G.A/PAM	2.5	6.0	5.0
2.5	G.A/PAM	4.3	11.7	10.7
3.0	G.A/PAM	2.7	9.2	8.2

TABLE 11: Viscosity measurement of gum Arabic/PAM blend at 50^0C

Concentration g/ml	Composition (70/30)%	Intrinsic Viscosity (Ns/m^2)	Relative viscosity (Ns/m^2)	Specific viscosity (Ns/m^2)
0.1	G.A/PAM	-7.0	0.3	-0.7
0.5	G.A/PAM	2.4	2.2	1.2
1.0	G.A/PAM	1.4	2.4	1.4
1.5	G.A/PAM	1.5	3.2	2.2
2.0	G.A/PAM	1.2	5.3	4.3
2.5	G.A/PAM	2.4	7.1	6.1
3.0	G.A/PAM	2.2	7.6	6.6

TABLE 12: Viscosity measurement of gum Arabic/PAM blend at 50^0C

Concentration g/ml	Composition (90/10)%	Intrinsic Viscosity (Ns/m^2)	Relative viscosity (Ns/m^2)	Specific viscosity (Ns/m^2)
0.1	G.A/PAM	-10.0	0.02	-1.0
0.5	G.A/PAM	-2.0	0.01	-1.0
1.0	G.A/PAM	-0.9	0.1	-0.9
1.5	G.A/PAM	-0.5	0.2	-0.8
2.0	G.A/PAM	-0.4	0.3	-0.7
2.5	G.A/PAM	-0.2	0.5	-0.5
3.0	G.A/PAM	0.0	1.0	-0.0

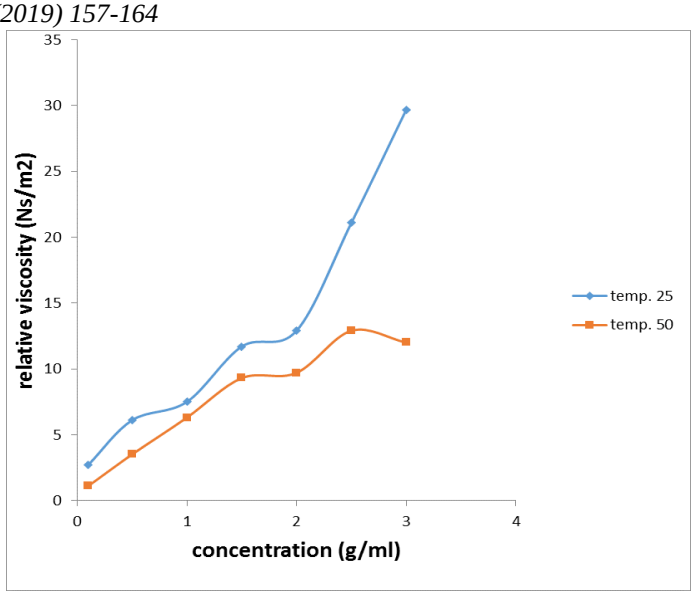

Fig.1 Relative viscosity Vs. concentration plots for Gum Arabic/PAM at 25^0C and 50^0C Composition of Gum Arabic/PAM: 10%/90% relative viscosity

TABLE 13: Viscosity measurement of 100% PAM at 50^0C

Concentration g/ml	Composition 100%	Intrinsic Viscosity (Ns/m^2)	Relative viscosity (Ns/m^2)	Specific viscosity (Ns/m^2)
0.1	G.A/PAM	4.0	1.4	0.4
0.5	G.A/PAM	9.0	5.5	4.5
1.0	G.A/PAM	8.2	9.2	8.2
1.5	G.A/PAM	7.7	12.5	11.5
2.0	G.A/PAM	9.6	20.2	19.2
2.5	G.A/PAM	10.7	27.7	26.7
3.0	G.A/PAM	7.1	22.3	21.3

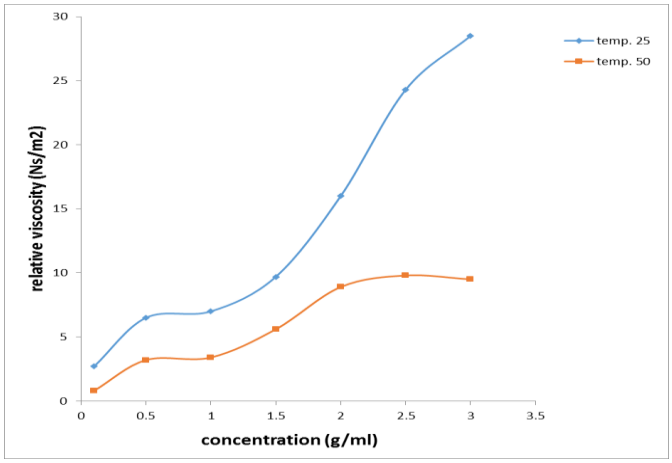

Fig.2 Relative viscosity Vs. concentration plots for Gum Arabic/PAM at 25^0C and 50^0C Composition of Gum Arabic/PAM: 30%/70%

From fig.5 the difference in viscosity at a temperature of 25^0C and 50^0C is more pronounced, since the increase in viscosity at temperature of 50^0C, is the same with that of the previous figure (i.e. fig.1-4).

But at a temperature of 25^0C there is very low flow rate of blend solution, which indicated that as the concentration of gum Arabic is increasing, there is decrease in viscosity of the blend. And this effect is more pronounced at low temperature.

TABLE 14: Viscosity measurement of 100% gum Arabic at 50^0C

Concentration g/ml	Composition 100 %	Intrinsic Viscosity (Ns/m^2)	Relative viscosity (Ns/m^2)	Specific viscosity (Ns/m^2)
0.1	G.A/PAM	-10.0	0.01	-1.0
0.5	G.A/PAM	-20.0	0.02	-1.0
1.0	G.A/PAM	-0.9	0.1	-0.9
1.5	G.A/PAM	-0.5	0.3	-0.7
2.0	G.A/PAM	0.3	0.4	-0.6
2.5	G.A/PAM	0.0	1.0	0.0
3.0	G.A/PAM	0.1	1.3	0.3

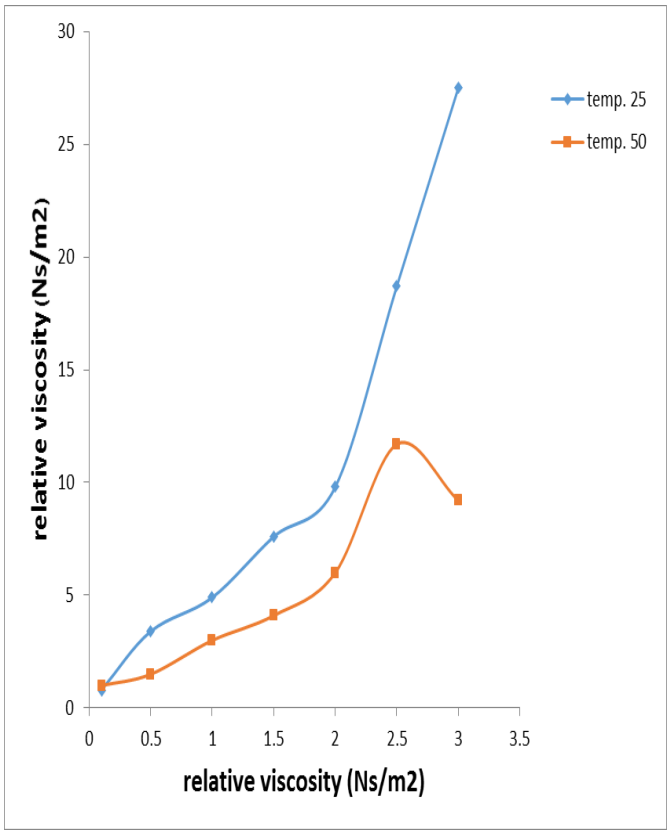

Fig.3 Relative viscosity Vs. concentration plots for Gum Arabic/PAM at 25^{0}C and 50^{0}C Composition of Gum Arabic/PAM: 50%/50%

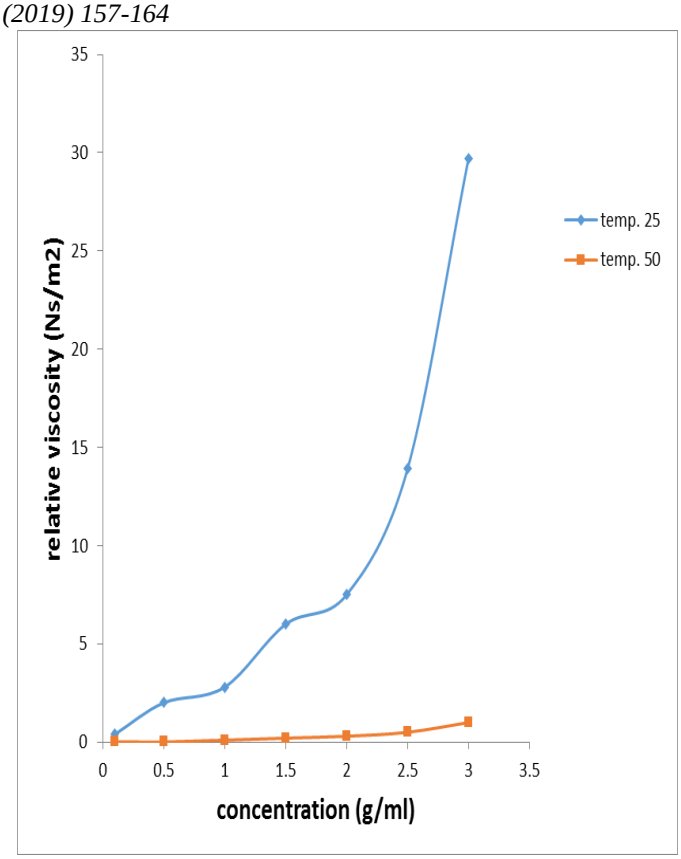

Fig.5 Relative viscosity Vs. concentration plots for Gum Arabic/PAM at 25^{0}C and 50^{0}C Composition of Gum Arabic/PAM: 90%/10%

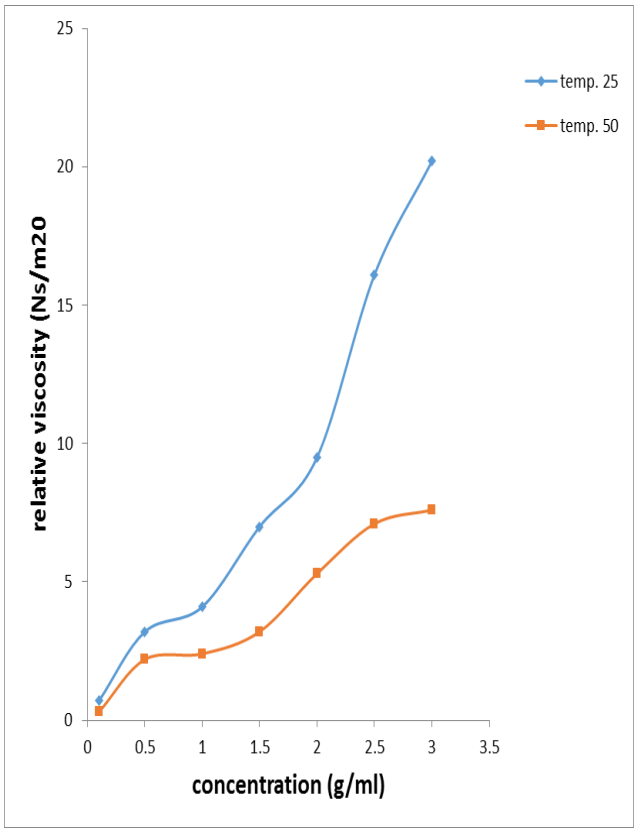

Fig.4 Relative viscosity Vs. concentration plots for Gum Arabic/PAM at 25^{0}C and 50^{0}C Composition of Gum Arabic/PAM: 70%/30%

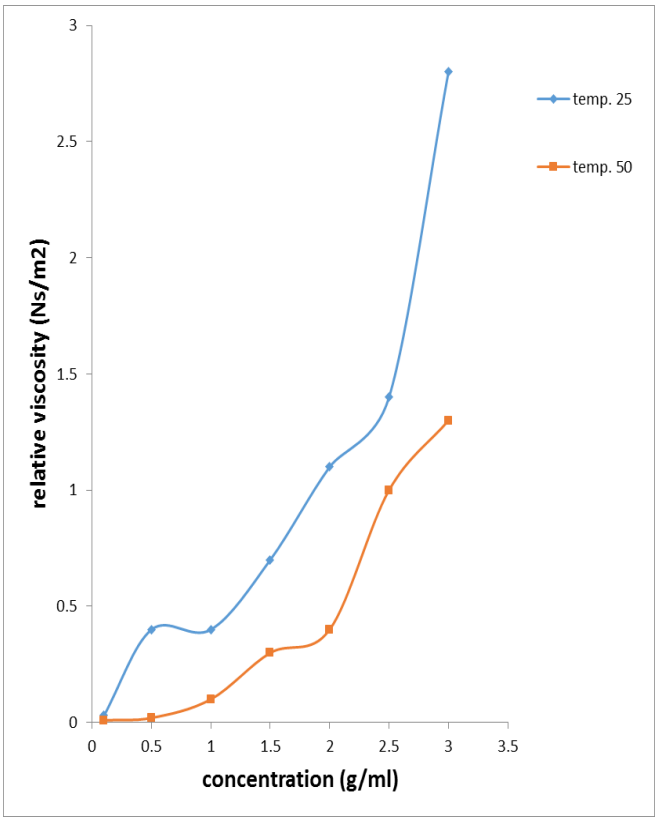

Fig.6 Relative viscosity Vs. concentration plots for 100% Gum Arabic at 25^{0}C and 50^{0}C Composition of Gum Arabic: 100%

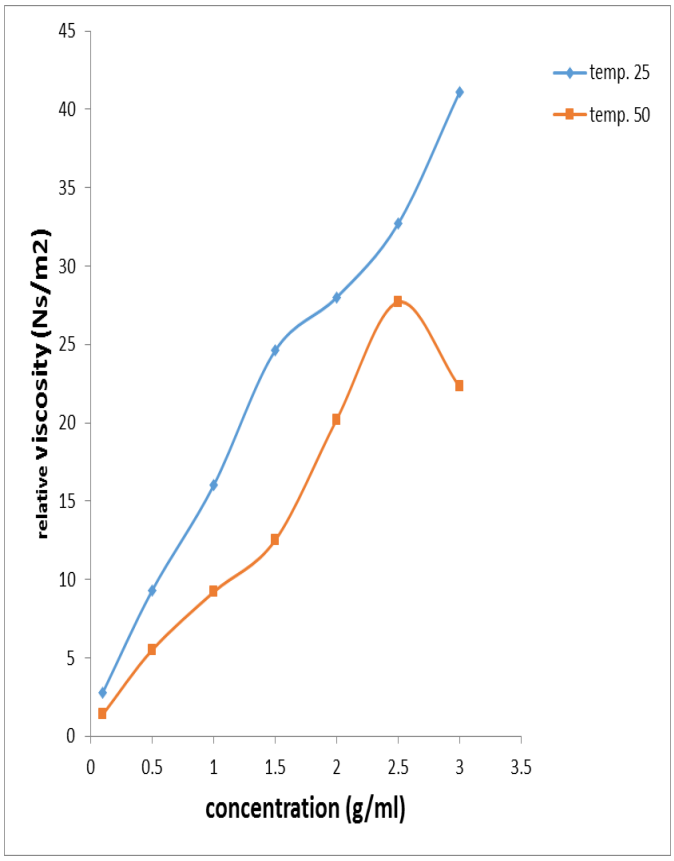

Fig.7 Relative viscosity Vs. concentration plots for 100% PAM at 25^0C and 50^0C Composition of PAM: 100%

In case of the observation, from fig.6 and 7 the same phenomenon is observed as from that of fig. 1-4 but the only difference is that; in fig.7, at a temperature of 250C, there is small decreased in in flow rate of blend at concentration of 2.5 Ns/m^2-3.0 Ns/m^2

In the case of the purification of gum Arabic it was founded that the colour of refined gum Arabic is dark-brown while that of raw gum Arabic to be orange-brown, and this change in colour is attributed to the types of solvent use for the purification of the gum Arabic. And it also confirmed that the solubility of the refine gum Arabic is higher than that of raw gum Arabic which is due to the presence of impurities in the former than that of the later.

It was also observed that, there is decrease in the flow rate of the polymer blend as the concentration of gum Arabic is increasing in all the composition, which indicated that the PAM is more viscous than gum Arabic. And also it was observed that as the temperature is increasing the flow rate of the blend is decreasing

At the end of the experiment, when the relative viscosity was ploted against concentration, straight line was obtained. And it is well known that from the previous knowledge (literature review) that when the viscosity of a solution is plot against concentration, if a straight line were obtained it indicated that the blend is compatible, but if the plot gives an S-type, it indicated incompatible polymer blend.

4. Conclusion

From the finding of the present study, the conclusion made are;

Blend of gum Arabic/PAM is compatible and the viscosity of each blend tend to increase with decrease in concentration of gum Arabic. And also the viscosity of the blend decrease with increase in temperature. It was discovered that the properties of gum Arabic like viscosity, clarity, solubility etc. can be improved.

It was also found that blend with composition of gum Arabic/PAM (10%/90%) to have a higher viscosity similar to that of individual PAM, and hence it is advised that the blend (gum Arabic/PAM (10%/90%) could be used in place of PAM, like in the field of; soil conditioner, water treatment, due to it lower cost than that of PAM.

The blend of gum Arabic/PAM (90%/10%) to have both solubility and viscosity almost the same with that of gum Arabic/PAM, for this reason it is advised to used blend of gum Arabic/PAM in placed of gum Arabic (100%), since the blend appear to possess properties closely related to that of gum Arabic used pharmaceutical and food industries.

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References

[1] U. W. Gedde, Crystalline polymers, in Polymer Physics. 1999, Springer. p. 131-167.

[2] J. P. Harmon,and L. M. Clayton, Polymer/carbon nanotube composites, methods of use and methods of synthesis thereof. 2008, Google Patents.

[3] F. Shakerian, et al., Advanced polymeric materials: Synthesis and analytical application of ion imprinted polymers as selective sorbents for solid phase extraction of metal ions. TrAC-Trend. Anal. Chem., 83 (2016) 55-69.

[4] M. A. Haney, The differential viscometer. I. A new approach to the measurement of specific viscosities of polymer solutions. J. Appl. Polym. Sci., 30 (1985) 3023-3036.

[5] Z. Awdeh, A. Williamson, and B. A. Askonas, Isoelectric focusing in polyacrylamide gel and its application to immunoglobulins. Nature., 219 (1968) 66-67.

[6] G. Williamson, and A. Cervenka, Characterization of low-density polyethylene by gel permeation chromatography-I the universal calibration curve and mark-houwink equation. *Eur. Polym. J.*, 8 (1972) 1009-1017.

[7] D. T. Stibbe, and J. Tennyson, Comment onPotential energy surfaces of excited states of H2. *Chem. Phys. Lett.*, 285 (1998) 114–120.

[8] S. Farshbaf, et al., Propargylic ureas as powerful and versatile building blocks in the synthesis of various key medicinal heterocyclic compounds. *Chem. Rev. Lett.*, 1 (2018) 56-67.

[9] E. Jafari, et al., An efficient and facile synthesis of the coumarin and ester derivatives using sulfonated polyionic liquid as a highly active heterogeneous catalyst. *Chem. Rev. Lett.*, 2 (2019) 123-129.
[10] F. Behmagham, Z. Asadi, and Y. Jamal Sadeghi, Synthesis, spectroscopic and computational investigation of bis (3-methoxyphenylthio) ethyl) naphthalene. Chem. Rev. Lett., 1 (2018) 68-76.
[11] D. E. Arthur, The use of strawberry and arabic gum blend as an inhibitor for the corrosion of aluminium in an acidic medium. *Chem. Rev. Lett.*, 2 (2019) 69-75.
[12] M. Dalen, and P. Mamza, Some physico-chemical properties of prepared metallic soap-driers of aluminium, copper and zinc. Sci. World. J., 4 (2009) 7-9.
[13] O. A. W. Ilavbare, et al., Hybridisation of Carbon Black: Cashew Nut Shell Powder as Fillers on the Mechanical Properties of Natural Rubber Composites. Compos. Mater., 2 (2018) 49-54.
[14] P. A. Mamza, et al., Comparative study of phenol formaldehyde and urea formaldehyde particleboards from wood waste for sustainable environment. Int. J. Sci. Technol. Res, 3 (2014) 53-61.
[15] J. R. Mujaheddin, K. Sheshappa Rai, and G. Guru, Miscibility studies of agar-agar/starch blends using various techniques. *Int. J. Res. Pharm. Chem.*, 2 (2012) 2231-2781.
[16] I. A. Khan, and E. A. Abourashed, Leung's encyclopedia of common natural ingredients: used in food, drugs and cosmetics. 2011: John Wiley & Sons.
[17] B. J. Palmer, Transverse-current autocorrelation-function calculations of the shear viscosity for molecular liquids. Phys. Rev. E., 49 (1994) 359-366.
[18] L. S. Lai, and H.-F. Chiang, Rheology of decolorized hsian-tsao leaf gum in the dilute domain. *Food. hydrocoll.*, 16 (2002) 427-440.
[19] T. Heitmann, and A. Mersmann, Determination of the intrinsic viscosity of native potato starch solutions. *Starch-Stärke.*, 47 (1995) 426-429.
[20] W. Yang, and M. Rao, Complex viscosity-temperature master curve of cornstarch dispersion during gelatinization. *J. Food. Proces. Eng.*, 21 (1998) 191-207.
[21] J. L. da Silva, M. Gonçalves, and M. Rao, Viscoelastic behaviour of mixtures of locust bean gum and pectin dispersions. *J. Food. Proces. Eng.*, 18 (1993) 211-228.
[22] B. G. Launay, B. Cuvelier, and S. Martinez-Reyes, Viscosity of locust bean, guar and xanthan gum solutions in the Newtonian domain: a critical examination of the log (ηsp) o-log C [η] o master curves. *Carbohydr. Polym.*, 34 (1997) 385-395.
[23] E. O. Kraemer, Molecular weights of celluloses and cellulose derivates. *Ind. Eng. Chem.*, 30 (1938) 1200-1203.
[24] T. Sornsrivichai, A study on rheological properties of tomato concentrates as affected by concentration methods, processing conditions and pulp content (viscosity, flow properties, tomato paste, food suspensions). 1987.
[25] T. Tanglertpaibul, and M. Rao, Intrinsic viscosity of tomato serum as affected by methods of determination and methods of processing concentrates. J. Food. Sci., 52 (1987) 1642-1645.
[26] D. E. Arthur, C. Gimba, and E.O. Nnabuk, Miscibility studies of cashew gum and khaya gum exudates in dilute solution by viscometry and FTIR analysis. *Am. J. Eng. Res.*, 8 (2014) 1-12.

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