INTERNATIONAL JOURNAL OF ENVIRONMENT
Volume-5, Issue-1, Dec-Feb 2015/16 ISSN 2091-2854
Received:26 October 2015 Revised:13 January 2016 Accepted:05 February 2016

DETERMINATION OF PHYSIOCHEMICAL PROPERTIES OF GUM ARABIC AS A SUITABLE BINDER IN EMULSION HOUSE PAINT

Ali .L. Yaumi[1]*, Ahmed M. Murtala[2], Habiba D. Muhd[3] and Fatima M. Saleh[4]
[1,2,3,4]Department of Chemical Engineering, Faculty of Engineering, University of Maiduguri, Borno State, Nigeria
*Corresponding author: aliyaumi@unimaid.edu.ng

Abstract

Gum Arabic "GA" is an organic adhesive produced from a tree called named Acacia Senegal. The gum has a wide range of industrial uses, especially in areas of feeds, textiles, and pharmaceuticals. It is used as emulsifier and serves mostly as stabilizer in both cosmetic and food products which contains oil water interface. GA sample was collected, formulated and prepared into various concentrations ranging from 20%w/v to 85%w/v. The quality and applicability of well characterized materials are directly related to their physical and chemical properties. From the physiochemical analysis, the result revealed that all the samples were slightly acidic (pH ranging from 4.81-6.41). This range is in good agreement with reported pH values for gum arabic and other *Acacia* gums by several authors. . The binding strength increases as the number of days increases for example in sample F (50%w/v) gum Arabic concentration increases from 1.5 in the 1st day to 1.97 in the 28th day. The samples prepared are denser than water which indicates that the density increases as the percentage concentration of the samples increases and the relative density of the gum solution is independent on time. The binding strength of sample G (75%w/v) gum concentration compared well to that of polyvinyl acetate (PVA).

Keywords: Gum Arabic, binder, polyvinyl acetate, physiochemical Properties

Introduction

Gum Arabic is an edible biopolymer mostly grown in the African region of Sahe in Sudan. Its exudates contains non viscous liquid rich in soluble fibres and emanates from the steams and branches which occurs under stress as a result of poor soil fertility, injury and drought (William and Phillips, 2000). GA is chemically a complex mixture of macromolecules consisting of different sizes and composition. The features and properties GA have been developed and is used in different industrial applications which include cosmetics and pharmaceuticals, textiles, ceramics, lithography, food etc. it is also used widely as thickener or emulsifying agent and stabilizer in the food industries (Verbeken et al., 2003).

GA is a colourless, tasteless, odourless, non-toxic and water soluble plant used mainly as a thickener and stabilizer in food industries. It does not alter the favours when used in foods. It is also used widely in bakery icing and crystallization inhibitor in sugar syrups as an adhesive and in beer as a stabilizer (Whistler et al., 1973). Due to its absorbing properties, GA is also used as stabilizer for frozen product like ice creams (Montgomery et al., 1959). GA has a very strong foam stabilizing ability which is used in the production of soft drinks and beer (Marline et al., 1992).

Binder are important part of house paint composition, solidify to form the paint coating. Binders can be natural or synthetic, simple or compound (glues, resins, gums, balsams, oils, waxes), whose main function is to hold together, firmly, the pigment particles. Typically, The term "gum" is used, in general terms, to define all those substances which come from the exudation of various trees, especially fruit, and that common denominator being soluble in water and insoluble in alcohols, oils and essences.

Polyvinyl acetate (PVA) is one of the principal raw material used to produce paints, but mainly imported in to the country and as a result it causes an increase the cost of production of paint. Gum Arabic is a natural biopolymer that is typically grown in Nigeria expecially in the northeast where they farm mostly grade 1, 2 and 3. Figures 1 and 2 shows the Gum Arabic (acacia) tree and Gum arabic sample used in this study.

With the known utility of Gum Arabic to different areas comes the enthusiasm to probe on more avenues at which it can still be placed into good use. Gum Arabic has been used in many industries as stabilizer, thickener, emulsifier etc. This research is geared towards investigating the suitability of using Gum Arabic solution as binder in emulsion paint which could serve as alternative to polyvinyl acetate (PVA) binder and determine the physicochemical parameters of the Gum Arabic solution.

Figure 1: Gum Arabic (acacia) tree

Figure 2: Gum Arabic sample

Materials and method

Sample collection

Samples of GA were purchased from Maiduguri Monday market, along Unguwan doki in Maiduguri town, Borno State, Nigeria, distilled water from Maiduguri water treatment plant Bama road, and the polyvinyl acetate was purchased at Agabus chemical Laboratory Kaduna**.**

Sample preparation

The crude gum Arabic sample was subjected to sorting in order to remove impurities that were not required for the work. The sample was then ground into fine powder and passed through a 212µm mesh screen. The prepared sample was then seated in containers and stored at room temperature.

Solution preparation

Four hundred grams of gum Arabic was dissolved in 2000mls of distilled water (20%w/v) for 24hr at room temperature. The solution was then stirred using Heidolph RZRI 50111 stirrer for 10 minutes until a homogeneous solution was obtained which gives a sample solution labelled "A".

The above procedure was repeated to obtain six more solutions labelled B (30%w/v), C (35%w/v), D (40%w/v), E (45%w/v), F (50%w/v), G (75%w/v) and H (85%w/v) respectively.

Determination of Physiochemical parameters

pH

The pH of the sample was measured using Hanna H198129 (pH meter). The pH meter was calibrated with distilled water before each use. The pH of the sample was measured by submerging the probe in the sample until the reading is registered by the meter.

Relative viscosity

The relative viscometer was determined using the standard method. The viscometer was inserted into the viscometer bath. A measured amount of the sample was poured into the U tube with capillary and corked. The U tube was suspended in the viscometer bath containing water. After sometime, the cork was removed and the time for the sample to run up from the top mark to the middle mark was measured using a stop watch. The viscosity was calculated as:

$$\text{Viscosity} = \frac{T - T_O}{T_O} \qquad (1)$$

Where; T = flow time of gum solution (sec.)

T_o = flow time of distilled water (sec.)

Relative density

The density of Gum Arabic sample was measured at room temperature using 20cm³ density bottles. The weight of clean dry density bottle was measured on a digital top loading balance as (M1). The density bottle was then filled with the sample solution and weight as (M2).

The density of sample solution calculated as:

Density = weight of the sample/volume of the sample = $\frac{M_2 - M_1}{20cm^3}$………………..2

Specific gravity

The specific gravity of the sample was measured at room temperature using specific gravity (SG) bottle. The Weight of empty specific gravity (SG) bottle was measured as M_1. The bottle was then filled with distilled water and weight M_2, the bottle was also filled with sample solution and weight M_3.The difference in the weight between the SG bottle filled with the sample and the empty SG bottle (M_3-M_1) divided by the weight of equal volume of water (M_2-M_1) gives the specific gravity of the sample.

Specific gravity = $\frac{M_3 - M_1}{M_2 - M_1}$……………………………..…………………..3

Refractive index

The refractive index of the samples was measured using Refractormeter 193. The surface of Refractor meter was clean using distilled water. A little amount of the sample was placed on the surface of refractormeter and reading was measured by refractormeter which was recorded by viewing through the hole of the refractormeter.

Binding strength

The binding strength of the gun samples was measured using a testometric 220D machines. The gum solution was apply between the two pieces of polymer material and was allowed to stick for 1 week. The stick sample was then placed and tight on the testing point of the testometric 220D machine and starts the machine. The machine measured and displays the breaking force in kilogram force (kgf) of the gum solution on the screen of the machine.

Specific volume

The Specific volume of a sample has been determined by taking the inverse of density.

$$\text{Specific volume} = \frac{1}{Density} \quad \ldots\ldots 4$$

Results and discussion

pH Test: Figure 3 shows the pH measurement of the formulated gum Arabic samples, the result revealed that all the samples were slightly acidic (pH ranging from 4.81 to 6.41). This range is in good agreement with reported pH values for gum arabic and other *Acacia* gums by several authors. (Yusuf, 2011).The acidity of plant gums is not unexpected since many of them are known to contain salts (Ca, Mg, K, Na and Fe) of acidic polysaccharides, the acidity of which is due to uronic acids in their structures (Abu Baker *et al.*, 2007; Ahmed *et al.*, 2009). The pH value of 5.04 of sample G (75%w/v) gum Arabic concentration was in good agreement with reported pH values for PVA (pH 3-5) *(*Rodriguez *et al., 2003)*. It can also be seen that, the acidity of gum Arabic samples increased with increasing gum Arabic concentration. As the number of days increases the acidity decreases for example in sample D (40%w/v) which has a pH of 5.81 in the 1st day and 4.62 in the 28th day.

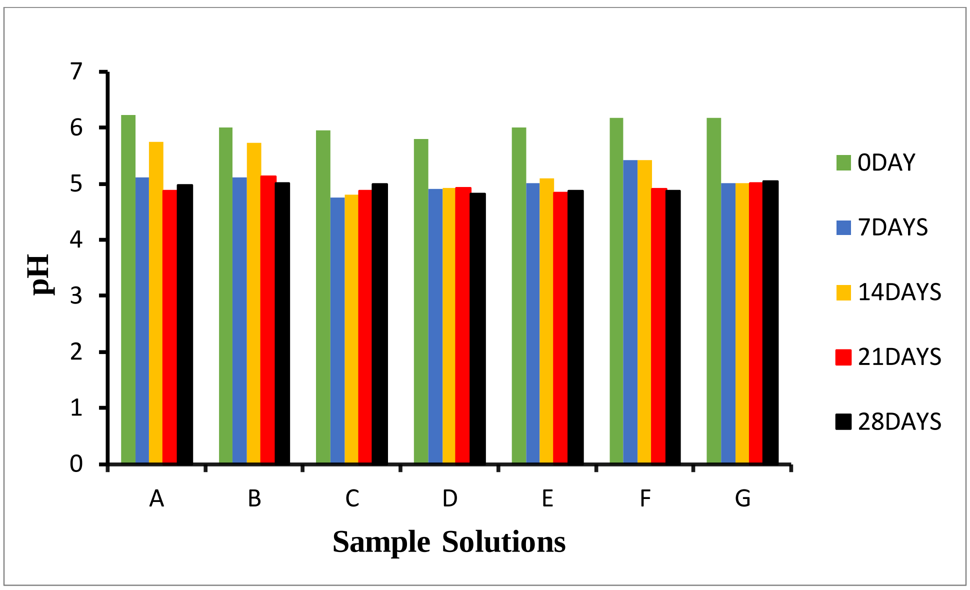

Figure 3: Graph of pH TEST

Binding strength: As expected, for all the gum Arabic samples, increasing the gum Arabic concentration was found to increase the binding strength of gum. This can be explained by the fact that increasing gum concentration increases particle cohesiveness and results in strong gum solution. From figure 4, the binding strength increases as the number of days increases for example in sample F (50%w/v) gum Arabic concentration increases from 1.5 in the 1^{st} day to 1.97 in the 28^{th} day. It can also be seen that, the binding strength of sample G (75%w/v) gum concentration compared well to that of polyvinyl acetate (PVA).This indicates that sample G (75%w/v) gum Arabic concentration can be used as substitute or supplement for PVA in terms of binding strength.

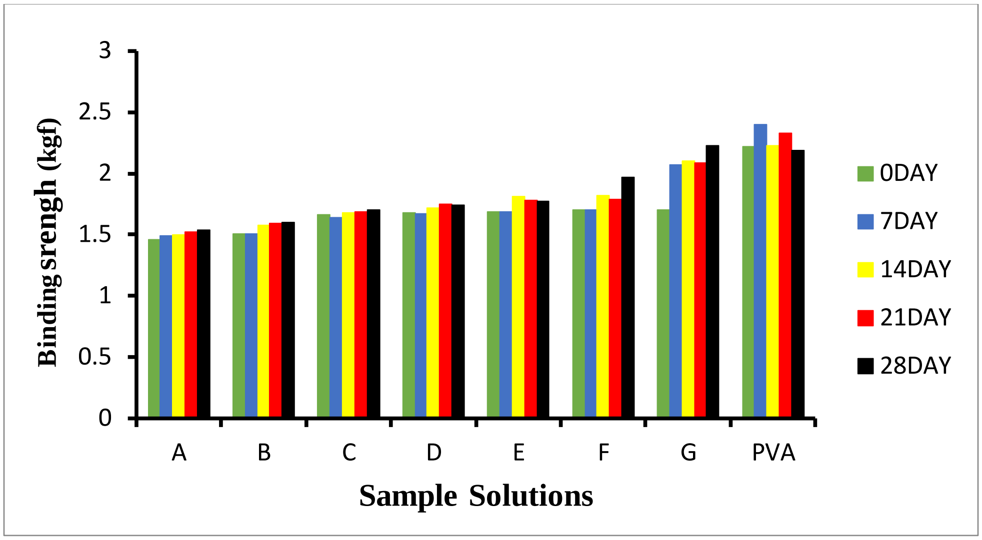

Figure 4: Graph of Binding strength

Relative viscosity: Viscosity is a measure of the resistance of a fluid to flow. Relative viscosity of the GA was found to depend on gum arabic concentration. In figure 5, it can be seen that, the relative Viscosity of gum solution increased with increase in gum concentration. According to Li *et al,* (2009), molecular association in fluids greatly influences their rheological behaviour.

The viscosity increases with concentration due to increase in number of high molecular weight polymeric chains of the gum Arabic per unit volume and the chain interactions in aqueous solution or dispersion. These are likely to increase cohesive density and therefore greater resistance to flow. However, higher relative viscosity values for sample G (*75%w/v)* gum solutions irrespective of concentration suggests the presence of higher molecular weight polymers in the gum's chemical constitution. it was observed that sample G (75%w/v) gum Arabic solution was fairly stable and the relative viscosity decreases as the number of days increases for example in sample C (35%w/v) gum Arabic concentration which has a value of

13.9 in the 1st day and 6.0 in the 28th day. It can be concluded that as the gum Arabic concentration increases the viscosity decreases.

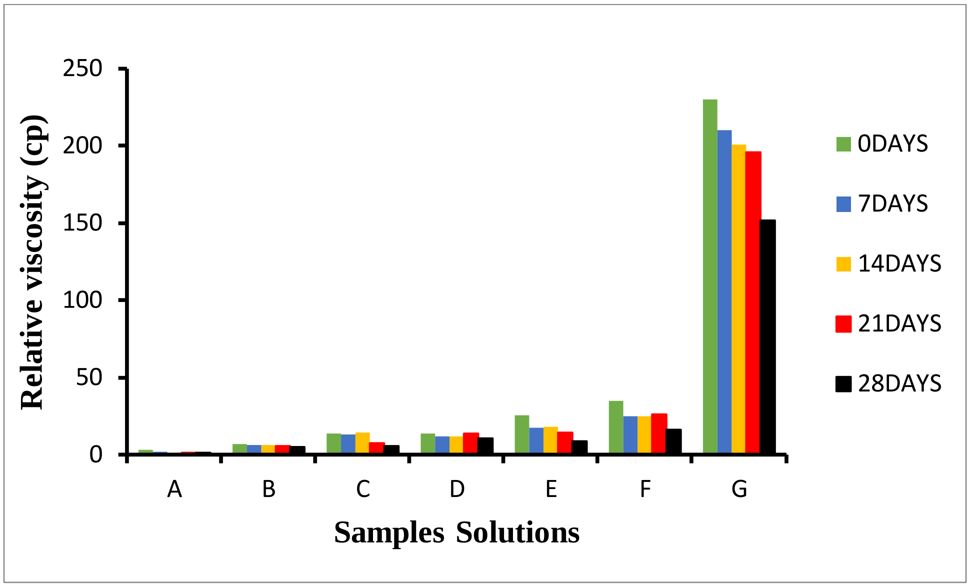

Figure 5: Graph of Relative viscosity

Relative density: Density is a measure of the degree of compact packing of macromolecules in the gums. Figure 6 shows the relative density of the gum Arabic solution., it can be seen that the relative density increased with increasing solution concentration with sample G (75%w/v) gum solution having the highest relative densities of 1.12 in the 1st day and 1.24 in the 28th day and 20% *solution* the least with 1.02 in the 1st day and 1.05 in the 28th day. Sample G (75%w/v) can be compared with the standard value of polyvinyl acetate of 1.30. Therefore, the relative density of the gum solution is independent on time.

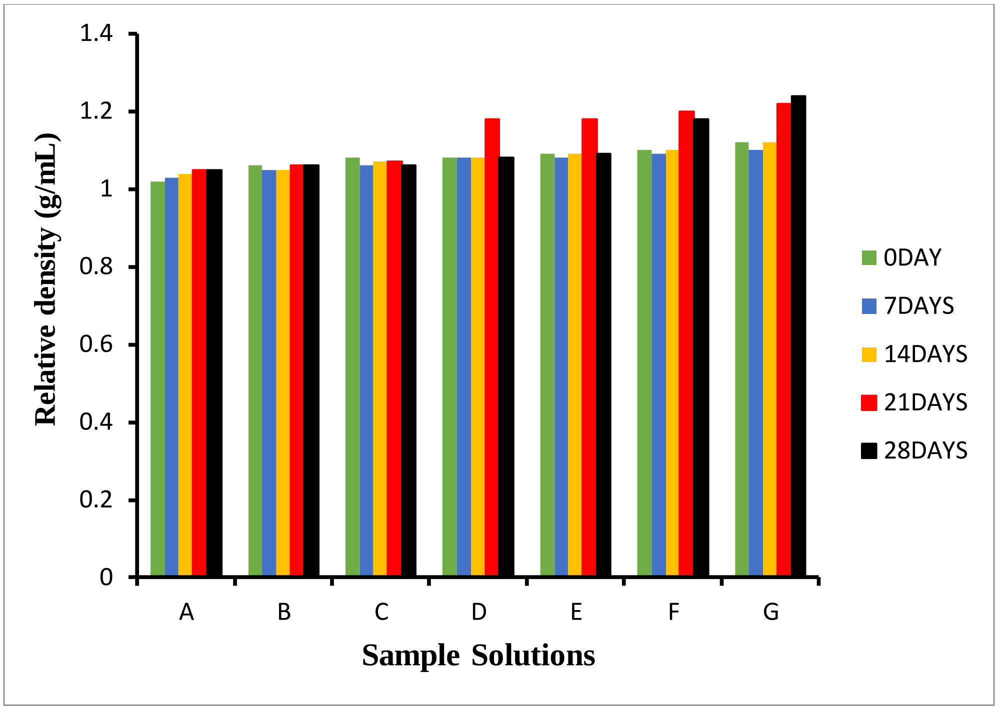

Figure 6: Graph of Relative density

Refractive index: Figure 7 shows the refractive index of the samples formulated using refractometer. The refractometer measures the index of refraction refraction by measuring the critical angle of total reflection. Samples A (20%w/v), B (30%w/v), C (35%w/v) and D (40%w/v) indicates sharp line between the bright & dark field. But samples E (45%w/v), F (50%w/v) and G (75%w/v) shows no line was visible due to their high concentration. Since the refractive index of a substance describes how light or any other radiation propagate through that substance as shown in figure 7, the refractive index of the samples is increasing as the percentage concentration of the gum solution increase.

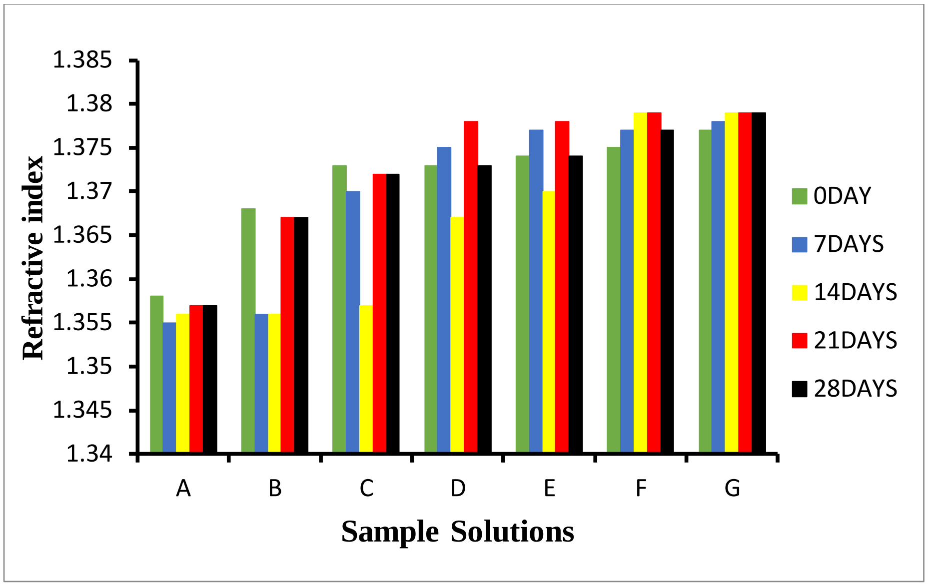

Figure 7: Graph of Refractive index

Specific volume: Specific volume is inversely proportional to density, it is the number of cubic centimetres occupied by one gram of the substance. Figure 8 shows the specific volume of the samples formulated. From the results of relative density in figure 6, it was shown that the gum Arabic relative density increased with increasing solution concentration and the gum solution is independent on time.

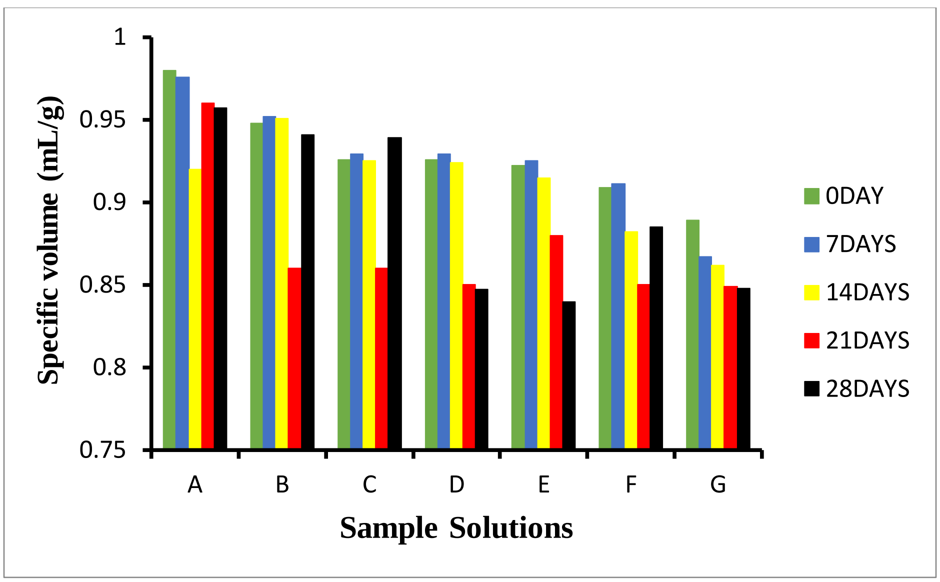

Figure 8: Graph of Specific volume

Specific gravity: The specific gravity of a liquid indicates how much more or less dense the liquid is compared to water. Water has a specific gravity of 1.00 this means that, if liquid is denser than water, then its specific gravity is greater than one. Figure 9 shows the specific gravity of the samples formulated. The result reveals that the entire samples prepared are denser than water which indicates that the density increases as the percentage concentration of the samples increases. It can be seen sample G (75%w/v) conforms well to that of polyvinyl acetate having standard specific gravity of 1.19 (Rodriguez et al., 2003).

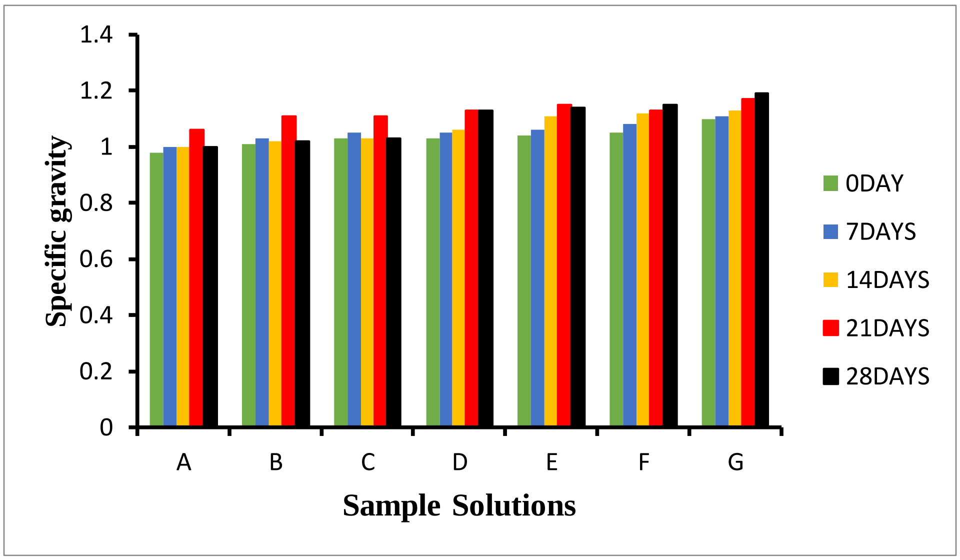

Figure 9: Graph of Specific gravity

Conclusion

Gum Arabic is derived from the exudates of acacia seyal and acacia Senegal trees which is a natural composite polysaccharide commonly used in industrial applications such as cosmetic, paints, food, adhesives, pharmaceuticals and print industries where they are used variously as dietary fibres, emulsifiers, stabilizers, food additives, thickeners, binders, suspending and surface coating agents. The GA sample was collected, formulated and prepared into various concentrations ranging from 20%w/v to 85%w/v. The quality and applicability of well characterized materials are directly related to their physical and chemical properties. From the physiochemical analysis, the result revealed that all the samples were slightly acidic (pH ranging from 4.81 to 6.41). This range is in good agreement with reported pH values for gum arabic and other *Acacia* gums by several authors. . The binding strength increases as the number of days increases for example in sample F (50%w/v) gum Arabic concentration increases from 1.5 in the 1st day to 1.97 in the 28th day. The samples prepared are denser than water which indicates that the density increases as the percentage concentration of the samples increases and the relative density of the gum solution is independent on time. It can also be seen that, the binding strength of sample G (75%w/v) gum concentration compared well to that of polyvinyl acetate (PVA).This indicates that sample G (75%w/v) gum Arabic concentration can be used as substitute or supplement for PVA in terms of binding strength .The results of this study support the gums' suitability for industrial application, especially in areas where commercial gum Arabic is traditionally used. Physicochemical data for the gum samples being formulated compared well with that of the polyvinyl acetate.

References

Abu Baker, A., Tahir, A. and Sabah Elkheir, M.K., 2007. Effect of Tree and Nodule Age on some Physicochemical Properties of Gum from *Acacia Senegal* (L.) Willd., Sudan. *Research Journal of Agriculture and Biological Sciences*, 3(6), 866-870.

Ahmed, S.E., Mohamed, B.E. and Karamalla, K.A., 2009. Analytical Studies on the Gum Exudates from *Anogeissus leiocarpus. Pakistan Journal of Nutrition*, 8(6), 782-786.

Li, X., Fang, Y., Al-Assaf, S., Phillips, G.O., Nishinari, K. and Zhang, H., 2009. Rheological study of gum arabic solutions: Interpretation based on molecular self-association. *Food Hydrocolloids*, 23 (8), 2394-2402.

Marline, B.S., 1992. Optimizing the adhesive property of plant exudates (gum arabic). M.Sc. Thesis, University of Jos, Nigeria. Pp 13-15.

Montgomery, R., 1959.The Chemistry of plant Gum and Mucilage. Reinhold Publishers, New York, Pp 494-498.

Rodriguez, F., Cohen, C., Ober, C.K., Archer, L. A., 2003. Principles of Polymer Systems, New York, USA, Taylor and Francis, 5th Edition, Pp 584-590.

Verbeken, D., Dierckx, S. & Dewettinck, K., 2003. Exudate gums: Occurrence, production, and applications. Applied Microbiology and Biotechnology, 63(1), 10–21.

Whistler, R.L., 1973. Industrial Gum Academic Press, New York, Pp 7-8.

Williams, P.A. and Phillips, G.O., 2000. Gum arabic. In: G.O. Phillips and P.A. Williams, Editors, *Handbook of Hydrocolloids*, Vol.9, C.R.C. Press New York, pp 155-168.

Yusuf, A.K., 2011. Studies on Some Physicochemical Properties of The Plant Gum Exudates of *Acacia senegal* (DAKWARA), *Acacia sieberiana* (FARAR KAYA) and *Acacia nilotica (*BAGARUWA). JORIND, 9(2), 1596 – 8308.