Study of Some Physicochemical and Functional Properties of *Acacia gerrardii* Gum from Sudan

Elassam. H. Ahmed[1], Asma, H. Mohammed[2], Adam A. Farah[3], Leila M. Mokhtark[4]

[1]Assistant Professor, Department, Chemistry, Faculty of Education, University of Kordofan, Sudan

[2]Associate Professor, Chemistry Department, Faculty of Science and Arts-Khulais, Jeddah University, Saudi Arabia

[3]Associate Professor, Department, Chemistry, Faculty of Education, University of Kordofan, Sudan
Corresponding Author Email Address: *adam1974999[at]gmail.com*

[4]Assistant Professor, Department of Chemistry, Faculty of Education, University of Kordofan, El-Obeid, Sudan, Now at Shaqra University, Kingdom of Saudi Arabia

Abstract: ***Acacia gerrardii Gum samples that were used in this work were collected from four different locations. Those locations are Khor Tamba, Bark Alla, Garduod Duleyba and Umshara, South Kordofan State, Sudan. Physicochemical properties of gum samples such as moisture, ash, protein and nitrogen contents, total soluble fiber, specific rotation, relative viscosity, intrinsic viscosity and pH have been investigated. It has been found that, there are noteworthy differences in these gum properties in this study. The gum from Bark Alla has higher protein content and intrinsic viscosity compared to the similar samples from three other locations; they were 33% and 244% respectively. The stability emulsion of Acacia gerrardii gum decreased with increasing the time. In contrast, the emulsion stability of gum raised up from 1.32 to 1.75 with rising stirring time from 1 to 5 minutes. Stability emulsion of Acacia gerrardii gum in regard to type of sesame and groundnut refined oils was investigated. Results indicate that using different types of oils results in significant differences in emulsion stability.***

Keywords: *Acacia gerrardii* gum, emulsion stability, intrinsic viscosity

1. Introduction

The State of South Kordofan lies within the semi-tropical climate, where the rainfall is high. It falls mainly in summer and ranges from about 300-800 mm[(1)]. The extreme of air temperature that have been recorded are 10-40℃. The mean relative humidity ranges from about 21% in the dry season to 75% during the rainy season [(2)]. The optimum temperature of growth is about 32℃, tropical trees require temperature below this [(3)].In Sudan, the gum belt is applied to that part of the country in which various types of gum are produced. There is a large variation of climate in the Sudan; from tropical forest in the south with an average annual rain fall of 500 mm and extensive savanna in the north. Rain fall is the most important climatic factor in the gum belt. Combined with soil conditions, average annual rain fall determines the location of the gum belt [(4)]. Non-cracking clay soil "Garduod" scattered mainly in southern Dar fur and south Kordofan, they present hard impermeable surface. Gums are high molecular weight polymeric compounds are capable of possessing colloidal properties in an appropriate solvent or swelling agent at low drying weight. Natural gums are those derived from plants and animals. Natural gums of plant origin seem to be associated with plant life processes. Gum *Acacia* is a dried gummy exudation obtained from trees of various species for the genus *Acacia*. The genus *Acacia* is very large and provides many complex botanical problems of nomenclature and classification. Today there are 1100 species known, distributed over tropical and subtropical areas of Africa, India, Australia, Central America and south west north America. There are many *Acacia* species in the Sudan. Sudanese gum of economic importance is in the order *Acacia senegal var. Senegal*, *Acacia seyal var. seyal* and recently *Acacia polyacantha*. Most of the research work on gum in Sudan is directed to gum Arabic, while other gum of Sudanese origin received less attention. Recently gum Kakamout has been characterized and started to gain some grounds in the gum market locally and internationaly[(5)].Gum *gerrardii* is a dried exudation obtained from stem and branches of the *Acacia gerrardii* trees, family *memosedeae* which widely spread throughout most tropical Africa to kwazulu Natal, South Africa, Zimbabwe, Botswana, Central African Republic, Chad, Ethiopia, Kenya, Nigeria, Rwanda, Sudan, Zaire and Zambia. Gum *gerrardii* as the majority of most Acacia gums stimulated by environmental conditions, mechanical injury of bark or invasion of plant by microorganism. Generally, *Acacia* Arabic gum can be used in many applications such as food industry, pharmaceutical [(6)], confectionary, bakery, beverage, cosmetics [(7)], chewing gum, fragrances and stabilizer, emulsifier, food[(8, 9)] industries, coating agent, oxidation inhibitor, texture, dietary fiber especially in western countries, and other industrial applications[(6)]. In the current work, physicochemical and functional properties of moisture, ash, protein and nitrogen contents, total soluble fiber, specific rotation, relative viscosity, intrinsic viscosity and pH for *Acacia gerrardii* gum have been investigated.

2. Materials and Methods

Gum samples of *Acacia gerrardii* were collected from four different locations in southern Kordofan State, Sudan. Samples were dried under the sun and purified from the bark of the tree and any other impurities then mechanically grinded by a crusher as previously reported[7].

2.1 Moisture, ash, protein, total soluble fiber

Ash and nitrogen were determined according to Association of Official Analytical Chemists (AOAC) as it has reported previously. Nitrogen was determined using semi micro Kejeldahl method [(9)]. 2 g of gum sample were accurately weighed in triplicate and placed in Kejeldahl digestion flask and one tablet (mercury-copper sulphate-potassium sulphate catalyst was added to each flask. Then 3.5 mL of concentrated free nitrogen sulphuric acid were added to the flasks. The contents were heated using hotplate until the solution attained a clear blue color, and the walls of the flasks were free from carbonized materials. The contents of the flasks were then transferred to a steam distillation assembly. The distillate was collected and dissolved in 50 mL of boric acid, distillation was continued after neutralization of the contents with 10 mL of 40% NaOH followed by 25 mL of distilled water to which three drops of methyl red were added and titrated against 0.01 M HCl. Similar procedure was carried out for blank (distilled water). Nitrogen was calculated as in the following equation:

$$N\% = \frac{14.04 \times N \times (V1 - V2) \times 100}{W} \ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where, **V1** is volume of the titrant, **V2** is volume of the blank; **N** is normality of HCl and **W** is the weight of sample in grams.
The protein content was determined by multiplying N% by nitrogen conversion factor (NCF), equals 7.0 for *Acaciagerrardii*[10].

$$Protein = N\% \times NCF \ldots\ldots\ldots\ldots (2)$$

Moisture content was determined by drying triplicate samples to constant weight in an oven at105°C. Overnight [(11, 12)]Total soluble fiber was obtained by subtraction of contents of moisture, ash and protein from 100.

2.2 The pH measurement

For measuring the pH for gum solution, it has done by taking 1% aqueous solution of gum (w/v) [(9)]. In this case, glass electrode pH-meter (HANA-pH 210) used in this study.

2.3 Gum specific rotation determination

Gum Specific rotation of samples that has been used in this study was measured by filtering 1% aqueous solution. That measurement has done by using digital ADP-410 Polarimeter that equipped with sodium lamp-20 cm path length [(9)].

2.4 Gum relative viscosity measurement

To measure the relative viscosity of *A. gerrardii* gum samples of 1% aqueous solution was flittered off by using Canon-fensky viscometer ASTM-IP (SIZE 100). Distilled water flow time was measured per seconds. The viscometer tube was filled at room temperature. The suction of the upper mark of viscometer was drawn. Then, distilled water was allowed to fall down passing the lower mark of the viscometer. Using stop watch both initial and final time were recorded during distilled water passing the Canon-fensky viscometer tube from upper and lower marks of the tube. The average time of the original solution and four of its dilutions was measured. The average flow time of three measurements were taken for each concentration. The viscosity can be calculated from the following equation [(9)].

$$\text{Relative viscosity} = \frac{T - To}{T0} \ldots\ldots\ldots\ldots \quad (3)$$

Where, Tis flow time of 1% *A. gerrardii* solution in seconds and T_o is Flow time of distilled as a solvent in seconds.

2.5 Gum emulsion stability

Two types of refined oil; sesame and groundnut and 2 % aqueous gum solution were used to prepare stock emulsions. Emulsions were prepared by blending 2% of gum solution with 2:1 v/v of oil that mentioned above for one minute at 1800 rpm using Heidolph DIAX 900 homogenizer. Triplicate preparations were made for each study. 1 mL of gum stock emulsion was diluted with distilled water to give final dilution of 1/1000.The absorbance was then read at 520 nm in spectrophotometer. Another reading of absorbance was recorded after an hour following the similar procedure as before [(13)].Emulsion Stability was calculated [(9)]: Emulsion Stability =First reading of absorbance Reading of absorbance after an

3. Statistical analysis

All data were analyzed using the method of complete randomized design (CRD), using excel computer programmed. F- Test was used to detect any significant differences in the reading of parameters. Tabular forms were produced including standard errors, coefficient of variation and square measurements.

4. Results and Discussion

4.1 Moisture content

Table (1) shows the contents of moisture, ash protein and total soluble fiber of *acacia gerrardii* gum collected from Khor Tamba, Barak Alla, Garduod Duleyba and Umshara and used in this study. Table 1 show that, the samples of *Acacia gerrardii*have significant difference of moisture contents depending on the sample's location. Location 1and 4 have no significant difference between them, their moisture contents of are 5.9 and 6.28 respectively. Location **2** and **3** have similar content of moisture 7.16 and 7.33 respectively. It can be concluded that, *acacia gerrardii* gum collected from Barak Alla has the highest moisture content in the comparison to other gums from other locations. These results were less than previously reported[(13, 14)]. It has been found that the moisture contents were 11-16.1% [(13)], and 14.25% [(14)]for the same gum from different locations. This might be due to the drying and storage conditions. Some of the variations in moisture content is due to whether the gum nodules are old or newly picked. The fresh nodules obviously have more water content. The moisture content of clean gum conforms to the value of < 15% set by Joint Expert Committee on Food Additives (JECFA)[(15)].

Table 1: Physicochemical property *Acacia gerrardii* gum in different locations

	Location (L)	Moisture content (%)	Ash content (%)	pH value	Optical rotation (%)	Nitrogen content (%)	Protein content (%)	Intrinsic viscosity	Emulsion stability ground nut oil	Emulsion stability sesame oil
1	KhorTamba	6.28 ^{b}	1.56^a	5.36^a	+55.92^a	1.74^b	12.26^b	33.42^c	0.67	**0.80**
2	Barak Alla	7.33^a	1.84^a	5.35^a	+30.29^b	4.72^a	33.01^a	224.19^a	0.79	**1.55**
3	GardodDuleyba	7.16 ^{a}	2.00^a	5.29^b	+49.00^a	1.69^b	11.85^b	21.70^d	0.51	**0.71**
4	Umshara	5.9 ^{b}	2.07^a	5.33^b	+51.33^b	2.18^b	15.25^b	67.04^b	0.61	**0.89**
SE ±		0.41	0.15	0.005	2.37	0.23	1.58	5.97	-	-
CV%		17.04	22.3	0.26	14	23.01	22.88	16.12	-	-

SE and CV% denotes for standard error and coefficient of variation, respectively.
Values having different letters are significantly different.
Values having the same letters are not significantly different.

4.2 Ash content determination

The ash content of the samples studied is in the range of 1.56 -2.07% as shown in table 1.The values obtained from different samples are from the same geographical location showed no significant variation in the ash contents and these results are in the disagreement with the results that has been reported[16] for *acacia Senegal* Sudanese samples, which was 3.6%. However, they are good agreement with results that previously reported[17], which were 2.37% [16] and 0.02-1.9% [17] of *Acacia seyal*. On the other hand, *Acacia gerrardii* showed generally higher ash content than other Acacia species which might be attributed to the presence of greater amount of some inorganic salts.

4.3 Nitrogen and protein content

Table 1 shows the nitrogen content of *Acaciagerrardii* samples in four locations. It can be noted that there are differences in the nitrogen contents in the gum depending on the locations that collected from. There are no big differences between location 1 and 3, the nitrogen contents are 1.74 and 1.69% respectively. Location 2 showed the highest nitrogen content, it is 4.74%. It has been reported that the nitrogen contents were 1.89 % [10, 18], but locations can be affected on the nitrogen contents and that the agreement with some literature[6, 9]. The age of gum trees or the type of the location soil can be affected on the gum nitrogen contents. The highest gum nitrogen content was in Barak Alla samples and that can be explained in terms of inactivation of an enzyme of the gum itself during storage period, or may be due to molecular rearrangement that may happen to protein molecules[19]. Nitrogen and protein squares of Acacia *gerrardii* were shown in table 2.

Table 2: Mean squares of some physicochemical properties of *Acacia gerrardii* gum samples

Source of variation	Degree of freedom	Moisture content	Ash%	Optical rotation(°)	pHvalue	Nitrogen content (%)	Crude protein	Total soluble fiber
Treatment	3	3.97^a	0.36$^{n.s}$	98.56^b	0.0059^b	15.083^b	742.56^b	0.00002$^{n.s}$
Error	26	1.236	0.245	42.089	0.0002	0.3894	18.77	0.0125

$^{\mathbf{a,\,b}}$denote for significant and highly significant difference, respectively. $^{\mathbf{n.s}}$, denotes for non-significant difference.

4.4 pH Value calculation

The pH of *Acacia gerrardii* gum has been investigated in this work. It can be seen that; the pH of gum is different depending on the gum locations. L1 and L2 show 5.36 and 5.35 respectively. L3and L4 showed 5.33 and 5.29 as pH results. Those results showed that, pH of L1 very close to L2 and L3 similar to L4. The difference may be due to the type of the soil of locations; L1and L2 showed higher pH in comparison to L3 and L4. The reason for that might because L1 and L2 have sandy and L3 and L4 have clay soils. Those results indicate that *Acacia gerrardii* gum is less acidic than that of *acacia seyal* gum of the same family as reported, 4.35- 4.74 for *varfistula*[20].

4.5 Specific rotation

The aqueous solutions of all samples were found to be optically active and rotate the plane of polarized light to the right. The angles of rotation of L2 samples were smaller than those of the remaining samples. *Acacia gerrardii* samples specific rotations were found in the range +30.29 to +55.9^o as has written in table 1. It can be seen that there are significant differences of gum depending on the gum locations. L1 shows the highest specific rotation in comparison to other locations. However, L2 showed only 30.29^o specific rotation. Previously, it has been reported that, specific rotation of *Acacia seyal* gum was +45^o [21] and +45 to+54^o [14]. These findings are in agreement with current results in this study. Actually, these results found in this study are less than that reported as +60^o [20], +50 to +60 [22].The differences in specific optical rotation values might indicate possibility of changes in carbohydrate composition according towho stated that specific rotation of gum is a linear function of its carbohydrate composition [23].

4.6 Viscosity measurements

Means absolute, relative, specific and reduced viscosity of Acacia *gerrardii* gum samples have been studied after diluting in water as a solvent. The results have been shown in table 3 for each gum location. The polysaccharides entities of which the gum is comprised are probably polymer which has in average molecular weight distribution, a variation in monosaccharides composition as well as a distribution in the mode of linkage and branching of certain monosaccharaides units. There is evidence from physical measurement to support this view, particularly from viscosity studies. The viscosity of a solution may have a complicated variation with Composition, due to the possibility of H-bonding among the solute and the solvent molecules. Excess hydroxyl groups lead to give high viscosities of gum solution as shown in this current work. A network of H-bonds is formed between molecules; it extends throughout the liquid, thus making flow difficult. The commercial value of the gum depends mainly on its viscosity. This implies that gums are industrially demanded according to their viscosities. In contrast of many types of gums *Acaciagerrardii* is one of the high viscous gums. This high viscosity of *Acaciagerrardii* gum can stand as an argument for the industrial and commercial preference of the gum over many others[7, 9]. The differences between gum viscosities can be explained depending on the gum locations. Location can be played the role in the viscosity of gum samples as table 3 shows. The highest viscosity recorded was for the gum that collected from L2.

Table 3: Means of absolute, relative, specific and reduced viscosity of *Acaciagerrrardii* versus location

	Location	$\eta_{abs.}$ (second)	$\eta_{sp.}$	$\eta_{rel.}$	$\eta_{sp./con.}$
L1	KhorTamba	90.40	0.36	1.36	55.82
L2	Barak Alla	182.80	1.75	2.75	282.93
L3	GardodDuleyba	88.80	1.33	1.33	49.91
L4	Um Shara	108.00	0.62	1.62	97.10

Acaciagerrardii solution in H_2O, 25°C, gum concentration = 0.006 g/100 mL, and average flow time in seconds.

4.7 Relative viscosity measurements

In this study, the gum relative viscosity increases with increasing the concentration of gum in the solution. Table 4 shows that the relative viscosities were from 1.05 to 1.50 in 0.002 mL as a lower concentration. However, they were 1.63-4.06 in 0.01 mL as a higher concentration. In this study, Location 2 shows the highest relative viscosity in both low and high concentrations. Again as it mentioned above, commercial value of the gum depends mainly on its viscosity. This implies that gums are industrially demanded according to their viscosities. In contrast, it has been found that *Acacia gerrardii* gums is one of the high viscous gum has ever found[9]. This high viscosity of *Acacia gerrardii* gum can stand as an argument for the industrial and commercial preference in the comparison to other gums.

Table 4: Relative viscosity of A. *gerrardii* gum in different concentrations

Solution	η_{rel}	η_{rel}	η_{rel}	η_{rel}	Cong/100.mL
Location	1	2	3	4	
A	1.6541	4.0600	1.6390	2.2556	0.01
B	1.5037	3.3684	1.4586	1.7894	0.008
C	1.3533	2.7067	1.3533	1.5639	0.006
D	1.2030	2.1052	1.1729	1.3533	0.004
E	1.0827	1.5037	1.0526	1.1578	0.002

4.8 Intrinsic viscosity

The intrinsic viscosity was obtained by extrapolation of the plot of series gum concentrations against their reduced viscosities at zero concentration as figures 1 and 2 are showing. Intrinsic viscosities of *Acacia gerrardii* samples collected from four locations, Khor Tamba, Barak Alla, Gardod Duleyba and Um Shara were diluted in H_2O were 33.88, 224.18, 21.7 and 67 $cm^{-3}g^{-1}$ respectively as listed in table 1. It can be seen that there are significant differences of intrinsic viscosities depending on the gum locations. These results are higher than reported previously by Anderson [24, 25]. Barak Alla shows the highest intrinsic viscosity compared to same gum from different locations. That because part of the tree from which the gum is harvested[26]. Another reason for that is a tree ages[27], where old trees give high intrinsic viscosity than young ones. Additionally, dissolving gum molecules in water leads to increase the size of gums and make spongy gel with time, consequently the viscosity increases.

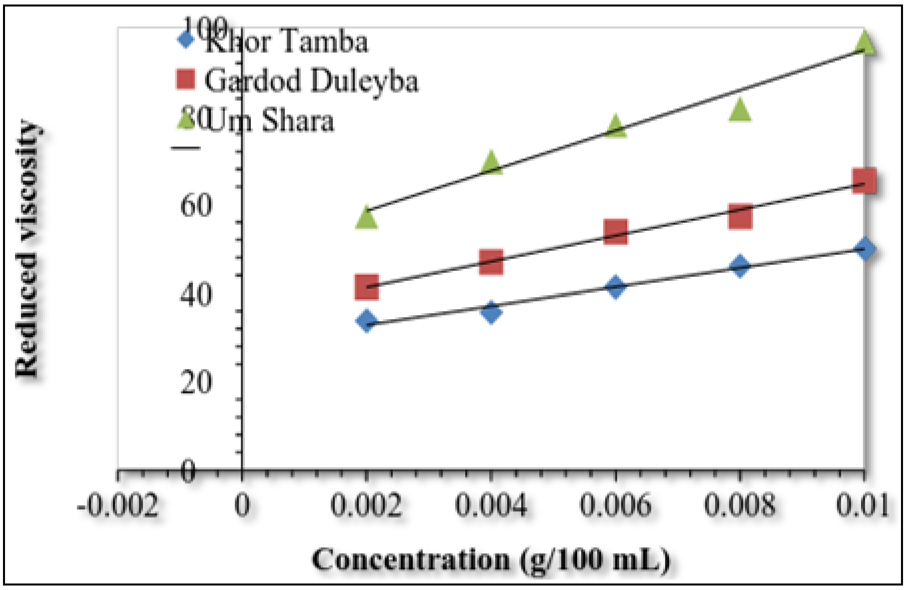

Figure 1: The standard Curve of Intrinsic viscosity

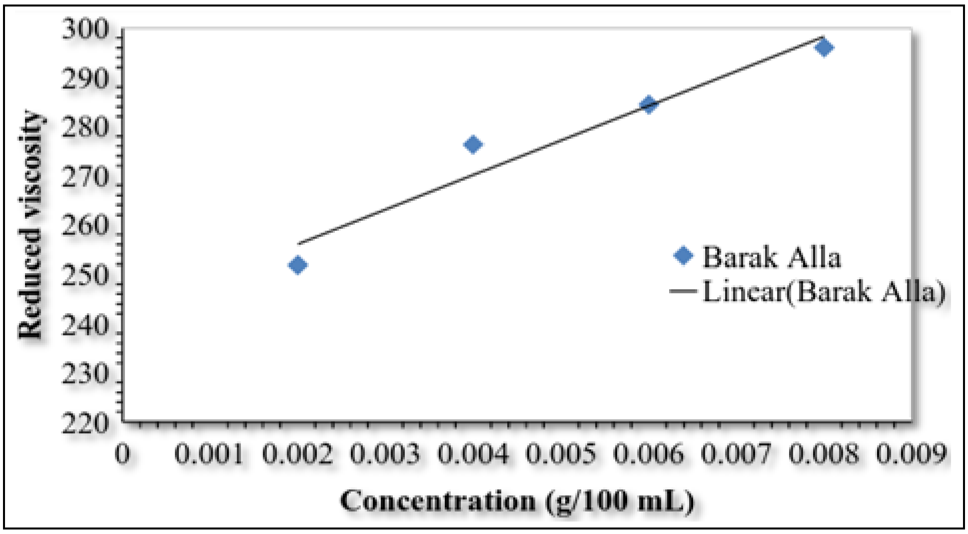

Figure 2: The standard Curve of Intrinsic viscosity

4.9 Emulsion stability

In this study, the gum emulsions were prepared by mixing pure of sesame groundnut oils with aqueous solutions of stable aqueous solutions of gum in the ranges 0.51 to 0.79 and 0.71 to 1.55. In this case, results indicate that using different types of oils resulted in significant differences in emulsion stability. Figure: 3 shows that, gum from L2 had the highest and L3 the lowest stability in both oils. That can be assigned as difference in protein content and as known protein is the fraction that provides the functionality of the gum as emulsion stabilizer(7, 8, 9). Therefore, the emulsion capacity and emulsion stability in regard to coalescence and flocculation were recorded in gums with highest nitrogen content(25). From Figure 3 it can be also seen that the stability of emulsion versus time per day. It can be seen that the stability decreases with increasing time per day. In the first day the stability was 1.2, but in the second and third days were 1.19 respectively and in the last day was 0.71.

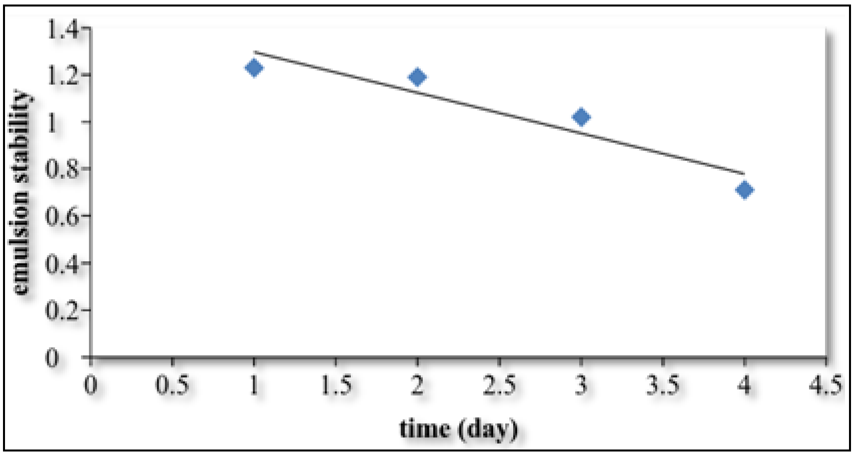

Figure 3: Emulsion stability of *A. gerrardii* gum

4.10 Stirring time

The effect of starring time on the stability of *A. gerrardii* gum has also been studied. It has been found that the stability of emulsions of gum is increased with increasing the stirring time from 1 to 5 minutes. In one minute, the stability emulsion was 1.32 and it increased to 1.75 in five minutes. Mechanical blending and homogenization affect droplets-size distribution and hence influences the properties of an emulsion. Droplets can be made smaller by applying more intense emulsification giving more stability. Figure 4 shows the effect of strring time on the stability of *A. gerrardii* gum.

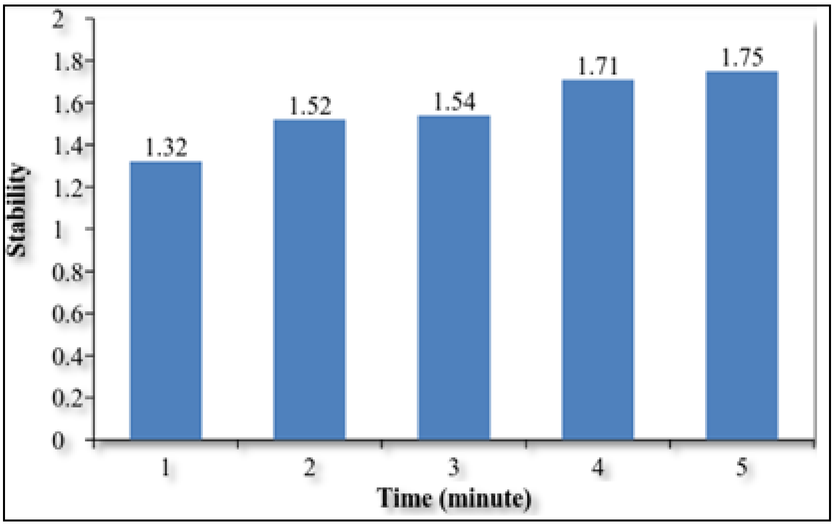

Figure 4: Stability of gum*Acacia gerrardii* under different stirring time

5. Conclusion

*Acacia gerrardii*gum is one of the high proteinaceous gums. Protein is the fraction that gives the gum the functionality as an emulsion stabilizer. Emulsion capacity and emulsion stability are generally found in high proteinaceous gums. *Acacia gerrardii* gum is a high viscous gum; this high viscosity can stand as an argument for the industrial and commercial preference over many other acacia gums.

References

[1] Keive, W.(1973). Climatic Zone in Sudan. SSA/WadMeddani, Sudan.
[2] Abd Ella, N. A. (2006). Ph.D. Thesis, University of Kordofan.
[3] Badi K. H. M, Ahmed A. E, Bayoumi, M.S. (1989). The forest of the Sudan. Forest National Corporation, Khartoum.
[4] Leyla, M.M.(2006) M.Sc. Thesis. University of Kordofan
[5] Hussein.M.S.(2006). M.Sc. Thesis. University of Kordofan
[6] K. K. Taha, R. H. Elmahi 1, E. A. Hassan, S. E. Ahmed and M. H. Shyoub, (2012), Journal of forest products and industries, vol.1, Pp: 11-16.
[7] Siddig. T Kafi, Murwan. K. Sabahalkhair, (2010), Effects of ã-Irradiation on Some Properties of Gum Arabic (Acacia Senegal L) Research Journal of Agriculture and Biological Sciences, 6(2): Pp: 113-117.
[8] EqbalDauqan and Aminah Abdullah, (2013), Utilization of Gum Arabic for Industries and Human Health, American Journal of Applied Science, vol. (10), Pp:1270-1279.
[9] Murwan K. Sabah El-Kheir, Abu El Gasim A. Yagoub and Asma A. Abu Baker, (2008), Emulsion-Stabilizing Effect of Gum from *Acacia Senegal* (L) Wild. The Role of Quality and Grade of Gum, Oil Type, Temperature, Stirring Time and Concentration Pakistan Journal of Nutrition, vol. 7, Pp: 395-399.
[10] Osman, M.E. (1993). Fractionation and Characterization Of Gum From *Acacia Senegal*, Ph.D. Thesis university of Salford U.K
[11] Association of official analytical chemists. (1990). Methods of analysis 15th ed. Arlington, VA, USA.
[12] Abu Baker, A.A., (1996). Analytical and structural studies on some plant gum exudates. M.Sc. Faculty of Agriculture, University of Khartoum.
[13] Anderson, D.M.W and Herbich, M.A (1963)"The composition and properties of 5. Gum nodules from *A. seyal* Del" *Journal of the chemical Soc. Part 1*:1-6.
[14] Menzies, A. R., Osman, M.E.; Malik, A. A. and Baldwin, T.C.(1996). A comparison of the Physicochemical and Immunological Properties of Plant Gum Exudate of *Acacia Senegal* gum Arabic and *Acaciaseyal* (Gum talha)
[15] JECFA-FAO(1982) Food and Nutrition paper No. 34
[16] Anderson, D. M. W.(1991).Gum Specifications. Food.J, vol, (93), Pp: 12-13.
[17] Hassan EA. (2000), Ph.D. thesis, Department of Food Science and Technology, Faculty of Agriculture, University of Khartoum, Sudan.
[18] Anderson, D. M. W. (1978).Chemitaxanomic Aspects of the Chemistry of Acacia Gum Exudates, Kewn Bull.;32; Pp: 529-536.
[19] Maxwell K. L., Bona, D., Liu, C., Arrowsh Smith, C. H., and Bord. A. M., (2003). "Refolding out of quinidine hydrochloride is an effective approach for high put. Structure Studies of small protein. *Sci*, 12. Pp: 2074-286.
[20] Karamalla, K.A (1965). Analytical and Structural Studies in the Polysaccharide Group. Ph.D. Thesis. Edinburg University.
[21] Anderson, D.M.W Dea, I.C. M, Karamalla, K.AandSmith, J.F. (1968).Analytical studies of some unusual forms of gum from *Acacia Senegal.Carbohydrate, Res.*6. Pp: 97-103.
[22] Anderson, D.M.W.and Yin, S. X.(1987).Food Additives and Contaminants; 5. 11.
[23] Biswass, B. Biswass, S, and Phillips, G. O.(2000). The relationship of Specific Optical Rotation to Structural Composition for *Acacia* and Related Gums. *Food Hydrocolloids*.14. Pp: 601-608.
[24] Anderson, D.M.W and Stoddart, J.F.(1966). Studies on uronic acid materials. Part XII. The composition of Acacia gum exudates, *Carbohydrate Res.*2.104-114.

[25] Vandevelde, M. C. and Fenyo, J. C. (1968). Macromolecular distribution of Acacia senegal by size excluion chromatography. Carbohydrate polymers, 5: 251-273.
[26] Duvallet, S. Fenyo, J. C., and Vandevelde. M. C.(1993). The Characterization of Gum Arabic from an Experimental Field of Ferlo NorthSenegal, *FoodHydrocolloids*, 7, Pp: 319-326.
[27] Idris, O. H. (1989).Physicochemical and microbiological characterization of *acacia Senegal*Ph.D. thesis, University of Khartoum, Sudan.
[28] Dickinson, E. (1992). An Introduction to Food pp:207.