



PRODUCTION AND PROPERTIES OF SEVEN ADHESIVES FROM GUM ARABIC (*Acacia senegal*)

*¹Ibrahim, U. G., ²Usman, A. H. and ²Abubakar, A. A.

¹Department of Chemistry, Kano University of Science and Technology Wudil, P.M.B. 3244.

²Department of Applied Chemistry, Federal University Dutsin-Ma, Katsina State.

*corresponding author's E-mails; umaribrahim@kustwudil.edu.ng

ABSTRACT

Adhesives are substances that are capable of holding materials via surface attachment that resist separation. They have wide applications in domestic and industrial areas. Seven different kinds of adhesives were produced using different reagents such (Na_2CO_3) with various concentration of 1%, 5%, and 10% designated as A,B and C, and caustic soda solution (NaOH) of 0.1M, 1M, and 5M concentrations designated as D1, D2 and D3 were prepared separately. Viscosity and drying rate of the adhesives were measured and holding capacity of each adhesive prepared were tested. From the result we observed that the seven adhesives produced has higher bonding ability on paper, wood and bank note compared to glass and ceramics since the adhesive produced are purely from the same natural resources.

Keywords: Adhesive, Gum Arabic, Caustic soda sodium carbonate and viscosity.

INTRODUCTION

Gum Arabic is an exudate natural gum. It's an important commercial polysaccharide which was used at least 400 years ago. The term gum was applied because the material has gummy characteristics and the name "gum Arabic" because the origin of export was an Arab area, and the Arabs in early history where the important traders and vendors of this material. (Barbosa, *et al.*, 2005).

Gum Arabic is usually produced from trees which belong to the genus acacia, sub family mimosoidea and family leguminosae. There are more than 500 species belonging to this family, distributed over the tropical and subtropical areas of Africa, India, Australia, central America, and south west North America. Despite periodical attempts to its texturing, film forming emulsifying, and stabilizing properties. (Barbosa *et al.*, 2005).

The Joint Expert Committee for Food Additives(JECFA) determined gum Arabic as a dried exudation obtained from the and branches of acacia Senegal will release species of acacia but, the gum from acacia Senegal is perhaps, the most valuable and widely used species of natural plant gums.(Shiva, 1993)

HISTORY OF GUM ARABIC

Gum Arabic was defined by the 31st Codex Committee for Food Additives, held at The Hague from 1923 to March 1999, as the dried exudate from the trunks and branches of Acacia Senegal or Vachellia (*Acacia*) seyal in the family Fabaceae (Leguminosae).(Ngara, 2004).

A 2017 safety re-evaluation by the Panel on Food Additives and Nutrient Sources of the European Food Safety Authority (EFSA) said that the term "gum Arabic" does not indicate a particular botanical source; in a few cases so-called "gum

Arabic" may not even have been collected from Acacia species (Mortensen, *et al.*, 2017).

In 1445, Prince Henry the Navigator set up a trading post on Arguin Island (off the coast of modern Mauritania), which acquired acacia gum and slaves for Portugal. With the merger of the Portuguese and Spanish crowns in 1580, the Spaniards became the dominant influence along the coast. In 1638, however, they were replaced by the Dutch, who were the first to begin exploiting the acacia gum trade. Produced by the acacia trees of Tarzan and Brakna, and used in textile pattern printing, this acacia gum was considered superior to that previously obtained in Arabia. By 1678, the French had driven out the Dutch and established a permanent settlement at Saint Louis at the mouth of the Senegal River, where the French Company of the Senegal River (Compagnie Française du Senegal) had been trading for more than fifty years. (Chisholm and Hugh, 1911).

For much of the 19th century, gum Arabic was the major export from French and British trading colonies in modern Senegal and Mauritania. France in particular first came into conflict with inland African states over the supply of the commodity, providing an early spur for the conquest of French West Africa. As the Atlantic slave trade weakened in the early 19th century, The Emirate of Tarzan and its neighbours, in what is today southern Mauritania, collected taxes on trade, especially gum Arabic, which the French were purchasing in ever-increasing quantities for its use in industrial fabric production. West Africa had become the sole supplier of world acacia gum by the 18th century, and its export at the French colony of Saint-Louis doubled in the decade of 1830 alone. Taxes, and a threat to bypass Saint-Louis by sending gum to the British traders at Portendick, eventually brought the Emirate of Tarzan into direct conflict

with the French. In the 1820s, the French launched the Franco-Tarzan War of 1825. The new emir, Muhammad al Habib, had signed an agreement with the Waalo Kingdom, directly to the south of the river. In return for an end to raids in Waalo territory, the Emir took the heiress of Waalo as a bride. The prospect that Tarzan might inherit control of both banks of the Senegal struck at the security of French traders, and the French responded by sending a large expeditionary force that crushed Muhammad's army. The war incited the French to expand to the north of the Senegal River for the first time, heralding French direct involvement in the interior of West Africa. (Webb and James, 2009).

Africa continued to export gum Arabic in large quantities—from the Sahel areas of French West Africa (modern Senegal, Mauritania, Mali, Burkina Faso, and Niger) and French Equatorial Africa (modern Chad) until these nations gained their independence in 1959–61. (Webb and James, 2009).

PHYSICAL PROPERTIES OF ARABIC GUM

Gum Arabic is amber, amorphous, highly viscous material when it is in fresh form and it is solid after contact with the atmosphere, it is light in colour with the shades of yellow, red or brown, depending on the sort of acacia trees, the four countries of origin and the condition of storage. It is nontoxic, odourless, tasteless, soluble in water giving a homogeneous colloidal and colourless system. The physical properties of Arabic gum is a natural product complex mixture of hydrophilic carbohydrates and hydrophobic proteins components emulsifier which adsorbs onto surface of oil droplets while hydrophilic carbohydrates components inhibits flocculation and coalescence of molecules through electrostatic and steric repulsion in food additives. (Ohwoavawohua, *et al.*, 2005).

CHEMICAL PROPERTIES OF ARABIC GUM

Gum Arabic is a natural polysaccharide of higher molecular weight, mainly calcium, magnesium, and potassium salt and potassium salts and some mineral elements, it is a water soluble polysaccharide of the hydrocolloidal group, on hydrolysis yield Arabic nose, galactose, rhamnase and glucuronic acid. It is a complex mixture of hydrophilic carbohydrate and hydrophilic protein components and comprised mostly of arabinogalactan and protein moiety. (Samia, *et al.*, 2009).

The chemical properties of gum Arabic quality are critical levels of foreign matter, acid insoluble matter, salt of sodium, calcium, potassium and magnesium, phosphorus, nitrogen and protein contents with no tannin content mineral contents. Mineral contain include copper, iron, manganese, zinc, carbon and molybdenum as well as very low level of arsenic, leads, cobalt, nickel, cadmium and chromium. Amino acids are the major constituents of the proteinaceous component of the Arabic with nitrogen content range 0.2 to 0.39%. Gum Arabic react with many reagents. As solution of gum Arabic will give precipitates or heavy gels if it is treated with the following reagents; borax, potassium, silicate, sodium silicate, melon reagents. In general, trivalent metallic softs will cause precipitation with gum Arabic 0.7. A solution of gum Arabic can be coagulated by ruthenium red, hexol nitrate, or desogengeigy.

Gum Arabic can be hydrolyzed when it is treated with dilute acids to give a mixture of L-arabinise, L-rhamnase, D-galactose, and D-glucuronic acid. It also reacts with nitric acid to give mucic, saccharide and oxalic acid. (Samia, *et al.*, 2009).

CHARACTERISTICS OF GUM ARABIC

Gum Arabic is a solid of a pale to orange brown colour which, when ruptured, secretes vitreous substances. Gum Arabic of excellent quality is tear shaped, round, with an orange-brown colour. After it is crushed or shattered, the pieces are paler in colour and have a vitreous appearance. (Jani, *et al.*, 2009).

ADHESIVES

Adhesive is any substance that is capable of holding materials together in a functional manner by surface attachment that resists separation. "Adhesive" as a general term includes cement, mucilage organic material that forms an adhesive bond. Inorganic substances such as Portland cement also can be considered adhesives, in the sense that they hold objects such as bricks and beams together through surface attachment, but this article is limited to a discussion of organic adhesives, both natural and synthetic. (Owen and Packer, 1990).

Natural adhesives have been known since antiquity. Egyptian carvings dating back 3,300 years depict the gluing of a thin piece of veneer to what appears to be a plank of sycamore. Papyrus, an early nonwoven fabric, contained fibres of reed like plants bonded together with flour paste. Bitumen, tree pitches, and beeswax were used as sealants (protective coatings) and adhesives in ancient and medieval times. (Kang, *et al.*, 2000).

TYPES OF ADHESIVE

Many types of adhesive are known and most of them are currently in use, and there is no absolute way of adhesive classification.

NATURAL ADHESIVES

Natural adhesives are primarily of animal or vegetable origin. Though the demand for natural products has declined since the mid-20th century, certain of them continue to be used with wood and paper products, particularly in corrugated board, envelopes, bottle labels, book bindings, cartons, furniture, and laminated film and foils. In addition, owing to various environmental regulations, natural adhesives derived from renewable resources are receiving renewed attention. (Sina, 2010).

NATURAL GUM

Substances known as natural gums, which are extracted from their natural sources, also are used as adhesives. Agar, a marine-plant colloid (suspension of extremely minute particles), is extracted by hot water and subsequently frozen for purification. Alginic is obtained by digesting seaweed in alkali and precipitating either the calcium salt or alginic acid. Gum Arabic is harvested from acacia trees that are artificially wounded to cause the gum to exude. Another exudate is natural rubber latex, which is harvested from Hevea trees. Most gums are used chiefly in water-remoistenable products. (Sina, 2010).

ANIMAL GLUE

The term animal glue usually is confined to glues prepared from mammalian collagen, the principal protein constituent of skin, bone, and muscle. When treated with acids, alkali, or hot water, the normally insoluble collagen slowly becomes soluble. If the original protein is pure and the conversion process is mild, the high-molecular-weight product is called gelatin and may be used for food or photographic products. The lower-molecular-weight material produced by more vigorous processing is normally less pure and darker in colour and is called animal glue. (Sina, 2010).

CASEIN GLUE

This product is made by dissolving casein, a protein obtained from milk, in an aqueous alkaline solvent. The degree and type of alkali influences product behavior. In wood bonding, casein glues generally are superior to true animal glues in moisture resistance and aging characteristics. Casein also is used to improve the adhering characteristics of paints and coatings. (Sina, 2010).

BLOOD ALBUMEN

Glue of this type is made from serum albumen, a blood component obtainable from either fresh animal blood or dried soluble blood powder to which water has been added. Addition of alkali to albumen-water mixtures improves adhesive properties. A considerable quantity of glue products from blood is used in the plywood industry. (Sina, 2010).

STARCH AND DEXTRIN

Starch and dextrin are extracted from corn, wheat, potatoes, or rice. They constitute the principal types of vegetable adhesives, which are soluble or dispersible in water and are obtained from plant sources throughout the world. Starch and dextrin glues are used in corrugated board and packaging and as a wallpaper adhesive. (Sina, 2010).

ADHESIVE MATERIAL

A great variety of polymer can be used in in adhesives application. The selection of adhesives depends upon the adherent and the end use consideration must be taken of such factors, porosity or non-permeability of the adherent, its polarity and its medullas of rigidity.

Virtually all synthetic adhesives and certain natural adhesives are composed of polymers, which are giant molecules, or macromolecules, formed by the linking of thousands of simpler molecules known as monomers. The formation of the polymer (a chemical reaction known as polymerization) can occur during a "cure" step, in which polymerization takes place simultaneously with adhesive-bond formation (as is the case with epoxy resins and cyanoacrylates), or the polymer may be formed before the material is applied as an adhesive, as with thermoplastic elastomers such as styrene-isoprene-styrene block copolymers. Polymers impart strength, flexibility, and the ability to spread and interact on an adherent surface—properties that are required for the formation of acceptable adhesion

MATERIALS AND METHODS

Materials

Conical flask

Volumetric flask

Measuring cylinder

- Sample cells
- Stirrer
- Fold paper
- Beakers
- Mortar and pestle
- Sieve
- Reagent bottle
- Electronic weighing balance
- Viscometer
- pH meter

Reagent Used

- Gum Arabic (from acacia Senegal specie)
- Soap powder (Na_2CO_3 , 1%, 5%, 10%), Chemical Purity: =99.95%, Grade: =99.99%
- Caustic soda (NaOH , 0.1M, 1M, and 5M), Chemical purity: =97.0%, Grade: =97.0%
- Water (distilled)

METHODOLOGY

PREPARATION OF GUM ARABIC

3Kg of Gum Arabic was brought at kurmi market Kano, it is obtained from Maiduguri and Jigawa area. And then washed it with distilled water in a beaker of 1000 Cm^3 to remove the dirty substances (which is mainly from stem during the extraction).

The colour was Golden yellow after the treatment and then drying, after 5days (125 hours) on exposure to air at a normal laboratory temperature and pressure (25°C—30°C) without penetrating of direct sun light.

After the Gum Arabic was dried and then grinded it using the mortar and pestle. After which it was mashed using small sieve which is (0.5mm diameter) to get a powdered form of Gum Arabic that can be readily to used or dissolved in the solvent.

PRODUCTION OF ADHESIVE

Basically three types of reagent were used to produce the adhesives, these are water (distil water), soap powder (Na_2CO_3) and caustic soda (NaOH) solution.

Starting with the latter one, three different concentration caustic soda were prepared 0.1M, 1M and 5M. 50g of Gum Arabic was measured using weighing balance and transferred to a beaker and 100ml of 0.1M caustic soda and mixed by carefully stirring the mixture with stirrer for 5 minutes, and

transferred to a conical flask labelled A. Sample B (of 1M caustic soda) and C (of 5M caustic soda) also prepared using the same procedure. (Partnaik, 2004).

The fourth adhesive type of soap powder solution form, three different concentration D1, D2 and D3 of 1%, 5% and 10% respectively. 1% soap powder prepared by dissolving 1g of soap powder (after carefully measured using sophisticated electronic weighg balance) in 100ml of distil water and stirred to get a solution of soap powder of 1% concentration. Where 5% and 10% were prepared by dissolving 5g and 10g respectively of gum Arabic in 100ml of distil water in stirred to get the solutions. (Partnaik, 2004).

All the three soap powder solutions were left for 24 hours (1day) to have absolute homogeneity. And they are like in appearance with slight difference in thickness and permanent milkcolour followed by the 5% and the 1% which is relatively less thick and faint milk colour.

Using the above three soap powder solution, tree different adhesives were prepared. 1% soap powder was mixed with 50g of the Gum Arabic and stirred gently to attained homogeneity. After 3 minutes of stirring in the beaker, it was left for 2 hours to obtain where adhesive. Then transferred to a conical flask and labelled D.

However, samples get homogeneity at variable rate of 5 minutes and 7mins respectively in sample E, it takes 2 hours 30 minutes to foam the adhesives while F takes 3 hours to be foamed.

The last adhesive was made using universal solvent i.e. water. 50g of Gum Arabic was dissolved in 100ml of distil water. The mixture was continuously stirred for 5minutes and allowed to bond themselves for 2 hours then transferred to the mixture in a conical flask and labelled G.

ADHESIVES TEST

DETERMINATION OF THE PYSICAL PROPERTIES (IN INTEREST)

The physical properties such as appearance and pH of adhesives were determined.

Appearance; was observed physically by looking carefully to the seven adhesives produced i.e. A, B, C, D, E, F and G.

pH; was determined using a pH meter.

QUALITY ANALYSIS

Quality analysis involves determination of the effectiveness of the properties interest which include bind -ability, viscosity and drying rate (cure time) of the adhesives.

Viscosity; adhesive viscosities were measured using the viscometer.

Drying rate; this was done by applying the adhesive on papers and bringing them into contact under normal pressure of 1 atm. Then the cure time was recorded for each adhesive produced.

TESTING WITH SELECTED MATERIAL

All the products were tested with paper, wood, paper-note (bank note), ceramic and glass. But it is bond with paper and wood are highly strong compare with bonding with ceramic and glass. This is because the adhesives and the two materials (paper and wood) are purely from the same natural source of plants.

RESULTS

Physical appearance of adhesives, Viscosity, cure time on paper, on wood, on glass, on ceramics and on bank notes were analysed after formations and the results were presented as follows;

Table 1: Physical appearances of all the produced adhesives after their formation

S/N	Adhesives	Physical appearance
1.	Sample A	Gelatinous Golden Colour
2.	Sample B	Gelatinous Brown Golden colour
3.	Sample C	Gelatinous pale Golden Colour
4.	Sample D	Gelatinous Milky Colour
5.	Sample E	Gelatinous precipitate light Golden Colour
6.	Sample F	Gelatinous Precipitate Golden Colour
7.	Sample G	Gelatinous Light Golden Colour

Table 2: pH of the various adhesives formed.

S/N	Adhesives	pH Reading
1.	Sample A	12.10
2.	Sample B	7.80
3.	Sample C	12.00
4.	Sample D	7.20
5.	Sample E	9.90
6.	Sample F	10.00
7.	Sample G	4.40

Table 3; Various Result of viscosity of adhesives. (with spindle number 1, 2, 3).

S/N	Adhesives	Viscosity (mPa)		
		Spindle 1	Spindle 2	Spindle 3
1.	Sample A	6.66	23.53	408.00
2.	Sample B	1.08	19.44	341.80
3.	Sample C	2.36	51.93	785.10
4.	Sample D	4.82	91.17	1301.00
5.	Sample E	3.69	60.57	1667.00
6.	Sample F	2.75	65.93	1037.00
7.	Sample G	4.27	87.37	1412.00

Table 4; Cure time of adhesives on paper after their formation

S/N	Adhesives	Cure time(minutes)
1.	Sample A	6.50
2.	Sample B	7.30
3.	Sample C	6.21
4.	Sample D	8.01
5.	Sample E	8.25
6.	Sample F	6.00
7.	Sample G	5.15

Table 5; Cure Time of adhesives on a wood after their formation

S/N	Adhesives	Cure time(minutes)
1.	Sample A	2.47
2.	Sample B	2.09
3.	Sample C	4.22
4.	Sample D	3.58
5.	Sample E	4.39
6.	Sample F	4.16
7.	Sample G	3.03

Table 6; Cure time of adhesives on glass after their formation

S/N	Adhesives	Cure time (minutes)
1.	Sample A	4.53
2.	Sample B	2.51
3.	Sample C	4.62
4.	Sample D	3.50
5.	Sample E	3.78
6.	Sample F	3.26
7.	Sample G	3.69

Table 7: Cure time of adhesives on ceramics after their formation

S/N	Adhesives	Cure time (minutes)
1.	Sample A	6.45
2.	Sample B	10.24
3.	Sample C	11.35
4.	Sample D	11.44
5.	Sample E	7.16
6.	Sample F	8.47
7.	Sample G	8.42

Table 8: Cure time of adhesives on a Bank notes after their formation

S/N	Adhesives	Cure time (minutes)
1.	Sample A	6.09
2.	Sample B	6.43
3.	Sample C	4.40
4.	Sample D	9.45
5.	Sample E	6.55
6.	Sample F	7.15
7.	Sample G	6.40

DISCUSSION

The tables above gives the results for various tastes including the physical appearance, pH, viscosity, and the test on different Materials such as paper, wood, glass, ceramics and bank note as discussed below.

Table 1: -

From the result above we observe that all the adhesives produced are gelatinous (sticky semi solid) and some are precipitated such as sample E and F. And the sample A, B, C and G are appear in Golden colour due to the predominant Gum Arabic, while sample D, E and F are appear in milky and light Golden precipitate due to the predominant of the soap powder (Na₂CO₃) and are appeared in milky and light Golden precipitate.

Table 2: -

From the result above we observed the various reading of pH meter ranging from 12.10 to 4.40, i.e. the value of 4.40 are acidic (which are moderately acidic due to the higher concentration of Hydrogen Ion H⁺) while the value of 12.10 are Basic (due to the higher concentration of Hydroxide ion OH⁻).

Table 3: -

From the result above we observed the viscosity of the whole adhesives produced, the viscosity of adhesives was determined using the three different spindles i.e. spindle 1, spindle 2, spindle 3.

For spindle 1; the viscosity of sample A, D, E and G, has higher viscose with the value of 6.66, 4.82, 3.69, and 4.27. While the sample C and F are moderately viscose with value of 2.36 and 2.75. And the sample B are less viscose with the value of 1.08.

For spindle 2; the viscosity of the sample D, G, F has higher viscose with the value of 91.17, 87.37, and 65.9. While the sample E, C, and A, are moderately viscose with the value of 60.57, 51.93, and 23.53. The sample B are less viscose with the value of 19.44.

For spindle 3; the sample D, E, F, and G has higher viscose with value of 1301.00, 1667.00, 1037.00, and 1412.00 while sample A, B, and C are moderately viscose with the value of 408.00, 341.00, 785 .10.

Table 4: -

From the result above we observed the different of the drying rate (cure time) on paper of the seven adhesives produced, from the sample A, to G while the value ranges between 6. 21 to 8.25. The sample C with value 6.21 has least

time to cure while sample E with value 8.25 has highest time to cure. And all the adhesives from A to G has cure time on paper which is less than 9 minutes.

Table 5: -

From the result above we observed the different of the drying rate (cure time) on wood of the seven adhesives produced, from the sample A, to G while the value ranges between 4.39 to 2.09. The sample B with value 2.09 has least time to cure while sample E with value 4.39 has highest time to cure. And all the adhesives from A to G has cure time on wood which is less than 5 minutes.

Table 6: -

From the result above we observed the different of the drying rate (cure time) on Glass of the seven adhesives produced, from the sample A, to G while the value ranges between 4.62 to 2.51. The sample B with value 2.51 has least time to cure while sample C with value 4.62 has highest time to cure. And all the adhesives from A to G has cure time on glass which is less than 5 minutes.

Table 7: -

From the result above we observed the different of the drying rate (cure time) on Ceramics of the seven adhesives produced, from the sample A, to G while the value ranges between 11.44 to 6.45. The sample A with value 6.45 has least time to cure while sample D with value 11.44 has highest time to cure. And all the adhesives from A to G has cure time on paper which is less than 12 minutes.

Table 8: -

From the result above we observed the different of the drying rate (cure time) on Bank note of the seven adhesives produced, from the sample A, to G while the value ranges between 7.15 to 4.40. The sample C with value 4.40 has least time to cure while sample F with value 7.15 has highest time to cure. And all the adhesives from A to G has cure time on paper which is less than 8 minutes.

CONCLUSION

All the adhesive samples produced are used for making bonds on different materials, and the P^H , Viscosity, and the cure time on materials such as paper, glass, ceramics and bank notes were measured and recorded. However, by comparing bonding ability of these seven different products of adhesive, it was observed that product have excellent adhesive property, and can also be employed in adhesive applications because they can serve as an adhesive of good quality. All the seven products can be employed in areas like paper, wood, glass, ceramics and bank note.

RECOMMENDATION

I Recommended for a Further Research can be carried on to advance that this work to be harmless and useful in our society e.g. office, school and homes. Since the adhesive produce are all from our natural resources.

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