

1- INTRODUCTION

1.1- General Introduction

There are more than 1100 species of *Acacias* distributed throughout tropical and subtropical areas of the world, most commercial gum arabic is derived from *Acacia senegal* var. *senegal* locally, known as hashab gum and as Kordofan gum in the world. Gum arabic has been known for many thousands of years and there are no artificial substitutes that match it for quality or cost of the production (Gabb, 1997).

The most important Non- Wood Forest Products (NWFP) in the Sudan is gum arabic which is the second export commodity and hard currency earner. In this respect, Sudan commands over 80% of the world's gum arabic production and trade (Chikami *et.al.*,1993).

Gum arabic (GA) from Sudan is a product of *Acacia senegal* and *Acacia seyal* species. *Acacia senegal* var. *senegal* is the only variety which grows in the Sudan and is the main source of commercial gum arabic (hashab). On the other hand, both varieties of *Acacia seyal* i.e. var. *seyal* and var. *fistula* are found in Sudan (Chikami *et.al.*, 1993).

Chemically, gum arabic consists mainly of high-molecular weight polysaccharides made up of rhamnose, arabinose, and galactose, glucuronic and 4-o-methoxylglucuronic acid, and the salts of calcium, magnesium, potassium, and sodium of the two acids (Gabb, 1997).

GA is being widely used for industrial purposes such as a stabilizer, a thickener, an emulsifier and an encapsulating in the food industry, and to a lesser extent in textiles, ceramics, lithography, cosmetic, and pharmaceutical industry and other application (Verbeken *et. al.* 2003).

One of the most important applications of gum arabic is in the health field; gum arabic used by ancient Egyptian and Arabic civilizations to treat a variety of medical conditions, from colds to leprosy and still

plays a role in modern food and medicine. Historically, it was used to treat skin wounds such as burns, cuts, or leprosy also it is used to treat digestive issues, gonorrhoea, coughs, dysentery, colds. Some of these uses still apply today (Arja *et al.*, 2011).

Acacia is known as a good source of dietary fiber because it contains about 90 percent soluble fiber. This type of fiber, which dissolves in water, is an important part of the diet. The fiber helps the digestive system from various diseases, it may also help to alleviate constipation by improving bowel movement, also fiber contained in gum arabic can promote the growth of good bacteria or normal flora inside the gut, these good bacteria or normal flora will later fight and suppress the growth of pathogen bacteria, this may help the immune system to work better. In addition to its functional properties, gum arabic is known and commonly used for reducing urea in the blood which helps patient with kidney failure and gout (Osman *et.al*, 2012). Moreover, the gum arabic contains a high percentage of some of essential mineral which are needed by human body. Human body requires abundant amounts of minerals for proper functioning. Minerals are used to promote health and help to carry out various body functions. Minerals like calcium, sodium; potassium and magnesium are considered as major minerals available in gums, while zinc, iron, manganese, phosphorous are miners.

Acacia polyacantha species (Kakamut gum) is one of the *Acacia* gums that its exudates are closely related to, and can hardly be distinguished from *Acacia senegal* exudates unless recognized by acknowledged gum expert or by studying the physico-chemical characteristics. The two species, *Acacia senegal* and *Acacia polyacantha* belong to the same group known as *Acacia senegal* complex. Both gum exudates, from this group of *Acacia* species, have a laevorotatory (-ve) specific rotation in contrast to the *Acacia seyal* complex which produce gum exudates, that

have a dextrorotary (+ve) specific rotation, other structural, botanical characteristics are noticeable even within the same species (Omer, 2004). In this research the glucuronates salts of Na, K, Ca, Mg and Fe were prepared from glucuronic acid contained in *Acacia polayacantha* gum.

1.2- objectives

- i.** To authenticate the sample of *Acacia polayacantha* gum by studying the physicochemical properties.
- ii.** To prepare glucuronic acid from *Acacia polyacantha* gum using ion exchange technique.
- iii.** To prepare glucuronates of Na, K, Ca, Mg, and Fe from glucuronic acid using ion exchange technique.
- iv.** To compare the physicochemical properties of *Acacia polyacantha* gum and physicochemical properties of prepared glucuronic acid and glucuronates sample.

1.3- Gums

Gums are high molecular weight polymeric compound composed of carbon, hydrogen, oxygen and nitrogen (Somaya *et.al.*, 2010), gums in the natural form are often polysaccharides or modified polysaccharides. Gums usually have colloidal properties and may produce gels when dissolved in suitable solvents. Commonly, the term gum was applied to the polysaccharide exudates from various plants, which produce viscous mixtures when dissolved in cold or hot water (Roy *et.al.*, 1959).

Plant gums are organic substance obtained as an exudation from fruit, trunk or branches of the trees spontaneously or after mechanical injury of the plant by incision of the bark, or after the removal of the branch, or after invasion by bacteria (Somaya *et.al.*, 2010).

1.4- Gum arabic

Gum arabic is an exudate natural gum. It is an important commercial polysaccharide which was used at least 4000 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 were the important traders and vendors of this material. More than 80 names have been used for the material, depending on the local area where it was collected and on its colour and grade (Blunt, 1926).

The term Gum arabic is used with varying degrees of precision by different groups of people. In the context of its use as a food additive the most recent international specification, published by FAO (FAO, 1990), defines Gum arabic as the dried exudation obtained from the stems and branches of *Acacia senegal* (L) Willdenow or closely related species.

The specification then proceeds to give limits for certain parameters which have been selected to try and ensure that only gum from *A. senegal* and closely related species satisfies the specification.

In Sudan, the term Gum arabic is used in a wider context to include two types of gum which are produced and marketed, but which are, nevertheless, clearly separated in both national statistics and trade; (Hashab) from *A. senegal* and (Talha) from *A. seyal*. In a still wider sense, gum arabic is often taken to mean the gum from any *Acacia* species, and is sometimes referred to as *Acacia* gum. gum arabic from Zimbabwe, for example, is derived from *A. karroo*.

In practice, therefore, and although most internationally traded gum arabic comes from *A. senegal*, the term gum arabic cannot be taken as implying a particular botanical source. In a few cases, so-called gum arabic may not even have been collected from *Acacia* species, but may originate from *Combretum*, *Albizia* or some other genus.

Generally the term gum arabic was used in the generic sense as any *Acacia* gum unless it is qualified by some other statement or the botanical source is specified (FAO,1990).

1.5- Description

A. senegal is a pale white to orange-brown solid, which breaks with a glassy fracture. The best grades are in the form of whole, spheroidal tears of varying size with a matt surface texture. When ground, the pieces are paler and have a glassy appearance.

A. Seyal is more brittle than the hard tears of gum arabic *A.senegal* (JECFA,1990).

1.6- Distribution

The gum belt agro-ecosystem refers to a broad band stretching across Sahelian regions of Africa and the Middle East situated between latitude 10° and 14° North. It starts from Mauritania in the West, through Senegal and Mali, Burkina Faso, Niger, Northern Nigeria to Sudan, Eritrea, Ethiopia, Kenya, Somalia and Northern Uganda in the East. It is also found in the Middle East, Yemen, India and Pakistan.

Sudan is the world's biggest producer of gum arabic, and since very little is consumed domestically it is also the main source of gum in international trade. The gum belt falls in central Sudan roughly between latitudes 10° and 14° North, with two areas outside these borders found in the north east (Faw, Gedaref and Kassala) and in the south east along the Blue Nile/Upper Nile border (Abdel Nour, 1997). It spans the traditional rainfed agricultural areas of western and central Sudan that include (Saverio *et.al.*):

- Kordofan Al Kubra 49.3% (N. Kordofan, W. Kordofan and S. Kordofan),
- Darfur Al Kubra 24.4 % (W. Darfur, N. Darfur and S. Darfur),

- Kassala region 23.4% (Kassala and Gedaref)
- White and Blue Nile region 2.9% (White Nile, Sennar, Blue Nile).

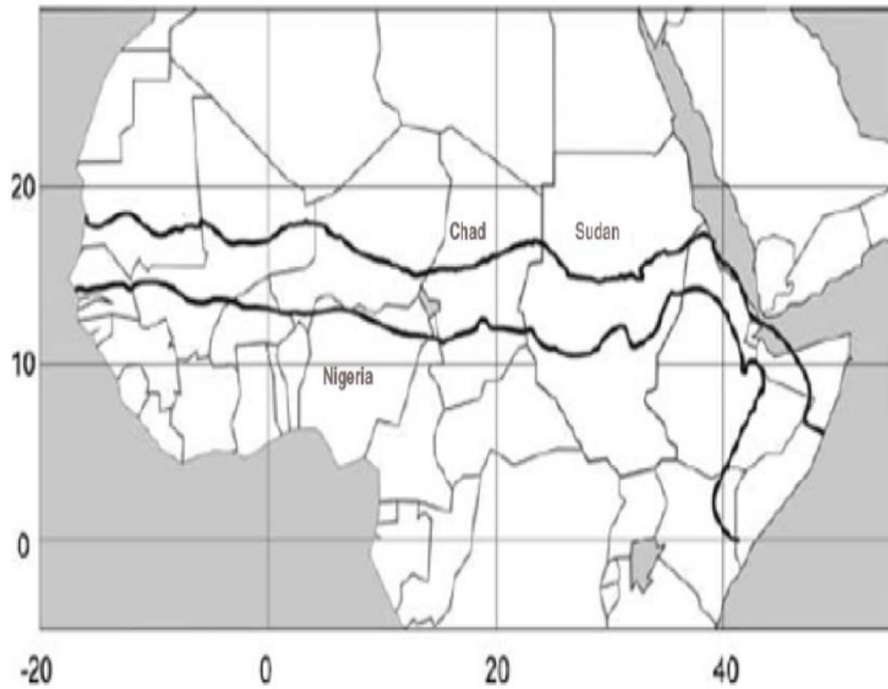


Figure 1.1: The gum Arabic Belt in Africa



Figure 1.2: The gum Arabic Belt in Sudan

Outside Africa, India produces small amounts of gum, similar in quality to gum (Talha), but a proportion of its exports of gum arabic consists either of re-exports of African gum or locally produced gum *ghatti* (from *Anogeissus latifolia*) misclassified as gum arabic.

1.7- Production of gum arabic

Most of the gum produced in the Sudan comes from *Acacia senegal* which growth to about 15-20 ft. tall and has a life of about 25-30 years. It grows in poor, sandy, reddish soil. It is found particularly in the district of Kordofan. The best quality of gum comes from *Acacia senegal* and is known as (Hashab) in the Sudan and also known as Kordofan gum.

90% of the gum produced in the Sudan is from these kinds of trees and about 10% of the gum comes from the *A. seyal* variety of *Acacia* which is known in the Sudan western part of the country and in the Nile region.

The gum from *A. seyal* trees is exuded naturally without tapping (Blunt, 1926).

During the rainy season, no gum is formed by the trees. So, the gum is collected during the dry season between October and May or June. A suitable age for trees which can be tapped is 6-7 years. Attempts to exudates gum from trees younger than this causes death of the trees. After a few weeks, the gum form in the cuts which is depending on the weather conditions is collected every 10 days during the season (Roy *et.al.*, 1959).

1.8- Gum from *Acacia Polyacantha* Tree

1.8.1- Classification of *Acacia polyacantha* tree

Family: *Leguminosae*.

Subfamily: *Mimosaceae*.

Genus: *Acacia*.

Species: *polyacantha*.

English name: Falcon's claws *Acacia*.

Arabic name: Kakamut, Umsiniena (Amin, 1977 and Voget, 1995).

The generic name 'acacia' comes from the Greek word 'akis', meaning a point or a barb. The specific name 'polyacantha' is based on the Greek word for many thorns.

1.8.2- Description

The tree, occasionally, reaches 20 m in height and the trunk can be 70 cm in diameter. A knobbly bark and paired thorns are it's most conspicuous features. The bark is yellowish with brown scale and thorn. Thorns occur in pairs and are sharply curved; they are brown with black tips. Leaves may reach 25 cm in length, biparipinnate with 10-40 pairs of pinnate and 35-60 of leaflets each. A prominent gland is present at the leave base. Flowers occur in pairs or 3 spicate racemes from the leaf axial

and are cream colored and strongly scented. Fruits consist of pods up to 15 cm long, which each contain 5-9 seeds (Voget, 1995).

Flowering August – September; fruiting December – March.

Habitat: Deciduous woodlands, riverine and groundwater forests. Usually gregarious along rivers and in rich alluvial valleys (Elamin, 1973).

1.8.3- General distribution

Acacia polyantha (Kakamut) is widespread in the Tropical Africa from Gambia to Ethiopia in the north and the Transvaal in the south. Also in Uganda, Kenya, Tanganyika and with – wards to Ghana, Nigeria, Dahomy, Ivory Coast Togo (Elamin, 1973). In Sudan there are several regional varieties, which usually occur along rivers and valleys where the water table is fairly high, and soils are good (Voget, 1995).

1.9- Chemical composition and structure of *Acacia* Gum

In recent years, several investigations have been conducted in order to reveal the molecular structure of GA and relate it to its exceptional emulsifying and rheological properties. The chemical composition of GA is complex and consists of a group of macromolecules characterized by a high proportion of carbohydrates (~97%), which are predominantly composed of D-galactose and L-arabinose units and a low proportion of proteins (< 3%) (Islam et al., 1997).

The chemical composition of GA may vary slightly depending on its origin, climate, harvest season, tree age and processing conditions, such as spray drying (Al- Assaf, 2005 (a,b); Flindt, 2005; Hassan , 2005; Siddig, 2005). Gum Arabic is recognized by many researchers that GA consists of mainly three fractions (Yael, 2006). Figure (1.3) shows the structure of gum Arabic:

- i. The major fraction is a highly branched polysaccharide consisting of galactose backbone with linked branches of arabinose and

rhamnose, which terminate in glucuronic acid found in nature as magnesium, potassium and calcium salt.

- ii. A smaller fraction is a higher molecular weight arabinogalactan-protein complex (GAGP-GA glycoprotein) in which arabinogalactan chains are covalently linked to a protein chain through serine and hydroxyproline groups. The attached arabinogalactan in the complex contains glucuronic acid.
- iii. The smallest fraction having the highest protein content is a glycoprotein which differs in its amino acids composition.

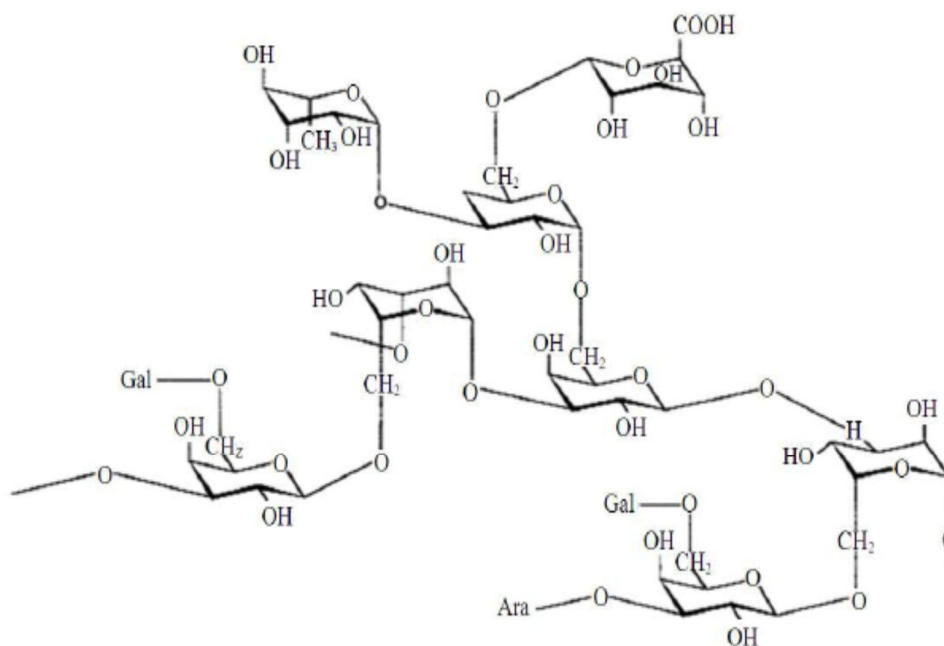


Fig 1.3 Structure of gum arabic

1.10- Physicochemical properties of gums

The physicochemical properties of the natural gum are most important in determining their commercial value and their use. These properties vary with gums different botanical source, and even substantial differences in gum from the same species when collected from plants growing under different climatic conditions or even when collected from the plant at different season of the year (Hirst *et.al.*, 1958). The physical properties may also be affected by the age of the tree and treatment of the gum after collection such as washing, drying, sun bleaching and storage temperature.

The physical properties of gum arabic, established as quality parameters include moisture, total ash, volatile matter and internal energy.

Gum arabic is a natural product complex mixture of hydrophilic carbohydrate and hydrophobic protein components emulsifier which adsorbs onto surface of oil droplets while hydrophilic carbohydrate component inhibits flocculation and coalescence of molecules through electrostatic and steric repulsions in food additives (Lelon *et.al.*, 2010).

GA physicochemical responses can be handled depending on the balance of hydrophilic and hydrophobic interactions.

The Moisture content facilitates the solubility of hydrophilic carbohydrates and hydrophobic proteins in gum arabic. Total ash content is used to determine the critical levels of foreign matter, acid insoluble matter, salts of calcium, potassium and magnesium.

The cationic compositions of ash content are used to determine the specific levels of heavy metals in gum Arabic (Lelon *et.al.*, 2010).

GA functional properties are closely related to its structure, which determines, for example, solubility, viscosity, degree of interaction with water and oil in an emulsion, microencapsulation ability, among others.

1.10.1- Colour

Colour is mainly due to the presence of impurities of some form or other, but the colouring matter in gums has been little investigated.

The best grades of gum are almost colourless with slight traces of yellow; some possess pink likes (Siddig, 2003) .Colour is of great importance in the commercial valuation of gums, a strong preference being always shown for those that are light coloured. After extensive observations, it appears that the old wood will give off a pinkish coloured gums " darker " where as the new wood i.e. the branches, give off a colourless or very light pink gums. The variability in colour is due to the age of the part of the tree.

The colour of gum arabic is different from year to year, depending on the climate. Pure gum *Acacia* ranges in colour from light amber to deep amber, is slightly cloudy and translucent when liquid, and in small amounts dries hard and transparent.

1.10.2- Shape

Natural gums are exuded in a variety of shapes and forms, usually the fragments are irregularly globular or tear globular or tear shaped. The best known being the tear or drop shape of various grades of gum arabic. Other shapes are flakes or threat like ribbons with *gum tragacanth*. The surface is perfectly smooth when fresh but may become rough or crusty, covered with small cracks (Omer, 2004).

1.10.3- Smell, Taste and Toxicity

True gums are generally scentless and tasteless but some are slightly sweet according to botanical origin (Howes, 1949).

Gum arabic occurs as non-toxic, tasteless and odourless material.

1.10.4- Solubility

Gums can be classified into three categories with regard to their solubilities:

- i. Entirely soluble gums: e.g. *A. senegal*, *A. seyal*.
- ii. Partially soluble gums: e.g. *Gatti gum*.
- iii. Insoluble gums: e.g. *Tragacanth gum* (Omer, 2004).

1.10.5- Moisture

The hardness of gum would be determined by moisture content. The moisture content of a good gum quality is in between 10 - 15% for granular and spray dried material respectively (FAO, 1999). The moisture content is weight lost due to the evaporation of water (Person, 1970). It shows the hardness of the gum and hence variability of densities, the amount of densities, and the amount of the air entrapped during formation. Omer (2004), reported that the moisture content of *A. polyacantha* gum to be around 8.2%.

1.10.6- Ash

Ash content is a measure of inorganic residue remaining after organic mater has been burnt. The inorganic residues exist as elements. Siddig (1996) explained that the type of the soil (clay or sand) affected the ash content significantly; previously the ash content for *A. polyacantha* gum was determined as 2.929 ash% (Anderson *et.al.*, 1985).

1.10.7- Nitrogen

According to studies of emulsifying behavior of gum arabic, there is strong correlation between the proportion of protein in the gum and its emulsifying stability (Dickinson, 1988). The protein contents of fresh samples were fairly constant (2%) irrespective of the age of the tree.

(Idris 1989). Siddig (1996) reported that the average value of nitrogen content of commercial samples of *Acacia senegal* gum and 80% of authenticated samples analyzed were in the range (0.27-0.39%). Recently Omer (2004) reported that the mean of nitrogen content of *A. polayacantha* gum samples was 0.35%.

1.10.8 Specific rotation

The optical activity of organic molecules (saccharides and carbohydrates) is related to their structure and a characteristic property of the substance (Stevens *et al.*, 1987). The gum of natural origin, e.g. *A. senegal* gum, has the property of rotating the plane of the polarized light. The direction of the rotation, as well as the magnitude is considered as a diagnostic parameter (Biswas *et al.*, 2000). *Acacia senegal* gum gives a negative optical rotation ranging between -20° to -34° . The optical rotation is used to differentiate between *A. senegal* and other botanically related *Acacia* gums. Anderson and Stoddart, (1966b) reported that the specific rotation for electrolysed *Acacia senegal* gum was $-31, 5^{\circ}$. Pure gum from *A. senegal* has specific optical rotation of -27° to -30° (Tioback, 1922). Certain variation in the degree of the optical rotation (-27° to -32°) has been noticed by (Anderson, 1968). Karamalla (1998) found that the mean of the specific optical rotation of commercial *A. senegal* gum was -30.54° . The optical rotation is not affected by both auto hydrolysis and variation, while mild acidic hydrolysis has a significant effect on optical rotation (Barron, 1991). Omer (2004) reported that the mean of specific rotation of authenticated samples of *A. polyacantha* gum was -16.6° .

1.10.9- Viscosity

The viscosity of liquid is its resistance to shearing, to stirring or to flow through a capillary tube (Bancraft, 1932). Studies of flow of gum solutions play an important role in identification and characterization of their molecular structure. Since viscosity involves the size and the shape of the macromolecule, it was considered as one of the most important analytical and commercial parameter (Anderson *et.al.*, 1969). The viscosity of a solution may have a complicated variation with composition, due to the possibility of hydrogen bonding among the solute and solvent molecules (Pimentel *et.al.*, 1960). More hydroxyl groups make high viscosities, because a network of hydrogen bonds is formed between the molecules, this net work extends throughout the liquid, thus making the flow difficult. The viscosity of gum solutions is inversely proportional to temperature. They also found that the viscosity of gum arabic solutions changes with pH, but they found a maximum viscosity at pH 6-7. Viscosity can be explained in different terms such as relative viscosity, specific viscosity, reduced viscosity, inherent viscosity and intrinsic; it is also represented as kinematics or dynamic viscosity. Anderson (1978) reported that the intrinsic viscosity of *A. polyacantha* gum was 15.8 ml/g. Omer (2004) recently reported 10.34 ml/g intrinsic viscosity for *A. polyacantha* gum.

1.10.10 Acidity and pH measurements

The hydrogen ion concentration is very important in chemistry and industry of gums, therefore functional properties of gum are affected by changes in pH e.g. viscosity, emulsifying power. Arabic acid substance is the major component of commercial gum arabic and when decomposed, it gives arabinose, so that the gum arabic is called Arabic acid and hence the gum solution is moderately acidic (pH= 4.5). Concerning the pH of

A. polyacantha gum Siddig (2003) reported a value of (4.9) and Omer (2004) reported 4.7-5.7 with a mean value of 5.2.

1.10.11- Apparent Equivalent Weight

According to the method reported in the Encyclopedia of Chemical Technology (1966) with some modifications; the aqueous gum solution 3% was treated with Amberlite Resin (120) (H⁺) (2 grams per 10 mls solution) then shaken for an hour and titrated against 0.02 N sodium hydroxide solution using phenolphthalein as indicator. The equivalent weight was calculated as follows:

$$\text{Equivalent weight (Eq. Wt)} = 50.000 \times 0.3 M$$

Where:

M = No. of ml of 0.02 N sodium hydroxide needed to neutralize 10 ml of 3% formulation solution.

0.3 = No. of grams of gum per 10 ml of the 3 % solution.

Anderson (1965) reported that the equivalent weight of *A. polyacantha* gum is 1900.

1.10.12- Molecular weight

The molecular weight of the polymers can be determined from physical measurement or by application of chemical methods. The applications of chemical methods require that the structure of the polymer should contain well known number of functional groups per molecule and they invariably occur as end groups. The end group analysis method gives an approximately number of molecules in a given weight of sample; they yield the average number of molecules for polymeric materials. This method becomes insensitive at high molecular weight, as the fraction of end groups becomes too small to be measured with precision (Meyer, 1971). This is due to the fact that fraudulent sources of the end groups not

considered in the assumed reaction mechanism steadily become consequential as the molecular weight increases and the number of end groups diminishes to such an extent their quantities determination is not feasible. Those reactions confine frequent application of chemical methods to condensation polymers with average molecular weight seldom exceeding 2.5×10^3 (Flory, 1953).

Physical methods frequently used for establishing polymer molecular weight are osmometry, polymer viscosity, measurement of coefficient of diffusion, ultra centrifugation and light scattering.

1.11- Emulsifying properties

Emulsions are chemical mixtures of liquids that are immiscible under ordinary conditions, and which may be separated into two layers on, standing, heating and freezing, by agitation and the addition of other chemicals (Encyclopedia, 1966). The emulsifying agents act as surface active agents, which when added to an emulsion it would increase its stability by interfacial action, each emulsifying agent depends on its action on different principle to achieve stable product. Gum arabic is used to stabilize flavor and oil emulsions in dried food mixes (such as soup, cakes,...etc) and the soft drinks industry, where the gum is required to stabilize a concentrated oil emulsion (about 20%) for long periods and also to continue to stabilize following dilution prior to bottling (Islam, 1997). An emulsifying agent is, usually a long – chain organic compound that has producing chains that are soluble in oil (lipophilic) as well as side chains or groups that are soluble in water (hydrophilic). Thus one portion of each molecule dissolve in the water phase while another portion dissolves in the oil phase and the main chain forms a link or bridge to keep both phases in position and there by emulsified. Gum arabic produces highly stable emulsions making it very useful in the preparation of oil in water food flavour emulsions particularly for citrus oils (Randall,

1988). Some believe that gums are not true emulsifiers. That is, they do not act by means of hydrophilic chemical functionality; they perform as emulsion stabilizers or protectors. Their function is essentially to increase the viscosity of the aqueous phase by thickening it so that it approximates or slightly exceeds that of the oil. In this way the tendency of the dispersed phase to slip or coalesce is minimized, and the emulsion, is so to be, stabilized. Such stabilization is a protective effect based on thickening properties of the gums. (Randall,1988) studied the effect of heat on the emulsification action, stability of the gum followed by changes in the GPC profile of the gum. He concluded that heating at 100°C for 3 hrs, results in a decreases in the intensity of the high molecular mass peak with a corresponding increase in the intensity of the lower molecular mass peaks. Continuous heating leads to further loss of the high molecular mass fraction and loss in the emulsifying stability of the gum. Chikamai (1993) reported that heating solutions at 100°C for more than six hours causes significant loss of emulsification properties; whereas, heating at 60°C for 24 hrs has only a minor effect. Dickinson (1988) studied the surface and emulsifying properties of six Acacia gum samples and stated that the relationship between nitrogen content and emulsifying properties of the gum samples, depend not only on their total protein content, but also on the distribution of the protein/peptide between the low and high molecular weight fractions, and on the molecular accessibility of the protein/peptide for adsorption. Dickinson (1991) studied the influence of the nature of the oil phase on emulsifying behavior of gum Arabic. They found that gum lowered the surface tension at the n-hexadecane-water interface also it gave the most stable n-hexadecane – water emulsion is smallest droplets with all three oils (n-hexadecane and orange oil). They also concluded that a high molecular weight fraction (0.87 nitrogen) corresponding to 10% of a natural gum

(0.38% nitrogen) gives initially larger droplets but better emulsion stability than the low molecular weight fraction (0.35%). In common with most emulsifiers, the AGP complex has a hydrophilic region (protein) and hydrophilic region (carbohydrate). During the formation of oil in water emulsions the protein (arabinogalactan) protein products in to the water phase. The bulk of gum arabic in the form of free AG can improve stability by increasing viscosity of the water (Islam *et al.*, 1997). The relatively low protein content of gum arabic requires high concentration of gum in most emulsification systems (Imerson, 1997). In this study a comparative emulsifying property of *A. polyacantha*, *A. senegal*, and *A. seyal* gum were carried out, effect of concentration, pH, addition of protein, blending, temperature and time of stirring investigated.

1.12- Modificatin of *Acacia* gum

1.12.1 Properties of *Acacia* gum

Acacia gum readily dissolved in cold and hot water in concentration up to 50%, because of the compact, branches structure and therefore small hydrodynamic volume, gum arabic solution are characterized by a low viscosity, allowing the use of high gum concentration in various applications (Dziezak, 1991). Solution exhibit Newtonian behavior at concentration up to 40% and become pseudo plastic at higher concentration. the pH of the solution is normally around 4.5-5.5, but maximal viscosity is found 6.0. *Acacia* gum has excellent emulsifying properties, particularly thanks to its AGP fraction. The hydrophobic polypeptide backbone strongly adsorbs at the oil – water interface, while the attached carbohydrate units stabilize the emulsion by steric and electrostatic repulsion. Fractionation studies show that, although emulsifying properties generally improve with increasing molecular weight and protein content, the best results are obtained with mixtures of

different fractions (Ray *et al.*, 1995). Seemingly, the heterogeneous nature of the gum makes it an excellent emulsifier (Buffo *et al.*, 2001); found that stability of beverage emulsions is influenced by a number of processing factors, such as pasteurization and demineralization, and by the pH of the emulsion.

1.12.2 Preparation of glucuronic acid

Until recently there was general method for preparation of glucuronic acid, this was the method used by Thomas and Marra (1982).

Glucuronic acid can be prepared by dissolving commercial gum arabic in about 0.1N hydrochloric acid. Ethanol was added with stirring and the precipitate was allowed to settle and then filtered out. The last step repeated four times to give a very pure product. The purified gum was redissolved in water and electrodialed for 50 hr. at which time a 1% solution showed a pH of 2.7. the final glucuronic acid kept in solution, since drying with ethanol or distilling under reduced pressure yielded an insoluble product (Thomas *et al.*, 1928).

Moorjani and Narwani (1948) prepared glucuronic acid by electro dialysis through cellophane, drying in a water bath, powdering and sieving through a fine mesh screen. They reported that drying glucuronic acid at 110⁰ yielded an insoluble material.

Recently Schleif and Co-workers prepared glucuronic acid by ion exchange method and successfully dried it by spray – drying at 205⁰ to yield a fluffy white, finely subdivided powder. A similar ion exchange method was used by wood to prepared glucuronic acid. This procedure was also used by Swintosky and Co-worker for the preparation of glucuronic acid and several other polysaccharides acids (Wood; 1954).

1.12.3- Preparation of glucuronic acid

Glucuronic acid is moderately strong acid having a pH of 2.2-2.7 in aqueous solution. For a moderately concentration solution, $K_a = 2.0 \times 10^{-4}$ at 22° , ranking it about the same as lactic as, stronger than acetic but weaker than chloroacetic acids. The values of K_a varies with concentration and $K_a = 1 \times 10^{-3}$ for a 5% solution and 2×10^{-7} at infinite dilution.

Glucuronic acid has an equivalent weight of about 1200 by various workers.

Upon addition of acid, glucuronic acid shows very little change in pH. The addition of neutral salts lower the pH of glucuronic acid solution. Glucuronic acid has lower viscosity than any of its salts or gum Arabic itself. Its viscosity can be lowered further by the addition of sodium chloride and lowered to an even greater degree by the addition of calcium chloride or similar divalent salts.

Emulsions prepared with glucuronic acid will cream rapidly and are not stable as those made with its glucuronic acid, divalent salts produce a greater decrease than monovalent salts. Pure glucuronic acid is non-reducing towards Fehling, solution and has specific optical rotation of -27° to 30° in water (Glicksman and Ralph; 1959).

1.12.4- Preparation of glucuronates

Several procedures have been reported for preparing gulucronates. According to Glicksman and Ralph (1959) sodium glucuronates can be prepared as follow:

(i) Krantz and Gordon (1929) precipitated the calcium ion in glucuronic solution by the addition of sodium carbonates. The solution is then filtered and evaporated to dryness to yield sodium glucuronate.

(ii) Briggs (1934) used direct neutralization of glucuronic acid solution with sodium hydroxide followed by evaporation to dryness under reduced pressure at 70°. Similar method has been used for preparing calcium glucuronate and other salts.

(iii) Schleif, Higuchi, and Busse (1951) prepared sodium glucuronates using ion exchange method. Glucuronic acid prepared by ion exchanging was treated with 0.5N sodium hydroxide until a pH of 8 was reached. The solution was then spray – dried at 205°C to give a fluffly, fine, white powder, this method was extended to prepare spray- dried glucuronates of potassium, calcium, magnesium, zinc, iron and aluminum. Wood also prepared glucuronates of iron, copper and silver by ion exchange procedure.

(iv) A more simplified one- step ion exchange process for preparing glucuronates was patented by Adams, glucuronic acid was passage through a cation- exchange resin in the salt form, a high purity glucuronates is formed potassium, sodium, lithium, and ammonium glucuronates were prepared.

1.12.5- Effect of cations on viscosity of glucuronic acid

In order to interpret the effect of the cations on the viscosity of gum Arabic and glucuronic acid it is necessary to review the viscosity studies made by Kruyt and Bungenberg (1949) on colloidal solutions.

It has been noted by these investigators that certain colloidal solutions which contain charged colloidal particles exhibit a peculiar type of curve when reduce viscosity was plotted against concentration. The influence of the ionic environment on the viscosity is a phenomenon very typical of solution of charged, solvated macromolecules. It is clear that in the presence of charges the skein will not assume its statistically most

probable form, but will have a less dense form through the interaction of the charged spots (mutual repulsion), or a more compact form if positive and negative charges are present simultaneously. As a result, the viscosity, which is sensitive to the form of the skein, is one of the most important aids in the investigation of systems with charged macromolecules. If there are only charged spots of one sign of the molecule, then the molecules will be relatively spread out. If charged spots of both signs are present, then the molecule will be more compact than corresponds to the most probable state. This remodeling of the skein not only depends on the interaction of the charged spots, but also on the extension of the ion atmosphere around each charged spot. The shape of the molecule will therefore also depend on the concentration and nature of different electrolytes in the solution, since these determine the thickness of the ion atmosphere.

When specific viscosity/concentration is plotted against concentration, Kruyt and Bungenberd (1949) observed, for agar and other colloids, that as the concentration is decreased the curve goes to a minimum, then at low concentrations a rapid rise in viscosity occurs. Due to the charge or the electro-viscous effect. It was also noted that electrolytes added to the colloidal solutions will suppress this charge, resulting in a curve which is linear. For colloidal solution with a negative charge the addition of an electrolyte with a divalent cation will result in a greater suppression of the charge, and a trivalent cation would suppress it further, suppression of the charge results in a more compact molecule; therefore, some of the water surrounding the molecule is squeezed out, resulting in less hydration and lowered viscosity. Self-suppression of the charge by colloidal particles at a higher concentration has been given as an explanation for the minimum in the curve discussed above.

Gum Arabic from which the glucuronic acid for the investigation was derived, is an example of a colloid with a negative charge. This charge is due to the carboxyl group in the molecule. It would be expected, therefore, that a charge would exist on molecules of glucuronic acid and its glucuronates as it does on gum arabic (Schleif, 1951).

1.13- Uses and applications of gums

Gum arabic is being widely used for industrial purposes such as a stabilizer, a thickener, an emulsifier and an encapsulating in the food industry, and to a lesser extent in textiles, ceramics, lithography, cosmetic, and pharmaceutical industry (Verbeken *et.al.*, 2003). In the food industry, Gum arabic is primarily used in confectionery, bakery, dairy, beverage, and as a microencapsulating agent.

1.13.1- Paper industry

Gum prevents dilatancy at high shear, helps regular distribution of pulp fibres, increases bursting strength decreases porosity and improves surface properties (FAO, 2007; Howes, 1949). Gum Arabic is used often as a lickable adhesive on postage stamps and cigarette papers (Wikipedia, 2007).

1.13.2- Textile industry

Gum is used as a thickening agent for pigment in printing fabrics. It prevents migration of dyestuff in pad dying operations, and produces very fine line prints with good definition and excellent washout (Coppen, 1995; FAO, 2007; Howes, 1949). Gum arabic is the traditional binder used in watercolor painting for artists, because it dissolves easily in water but no standards of purity for gum arabic used in printing-related applications. Printers employ it to stop oxidation of aluminum printing plates in the interval between processing of the plate and its use on a

printing press. Gum arabic suspends and binds the pigment to the paper surface, and creates a photographic emulsion, sensitive to ultraviolet light (Wikipedia, 2007).

1.13.3- Pharmaceuticals

Gums are principal components in pharmaceutical industries. Gum *tragacanth* is superior in pharmaceutical applications. Gum is used as suspending agent for insoluble drugs, demulcent agent, emulsification, antiseptic preparations, binder for tablets and tablet coating, jelly lubricants, spermicidal jellies and to mask the unpleasant taste of syrups. It is also used as a medicine for treatment for low blood pressure caused by hemorrhage or surgical shock. It is used topically for healing wounds and has been shown to inhibit the early deposition of periodontic bacteria and the early deposition of plaque (Coppen, 1995; FAO, 2007; Howes, 1949). Gum arabic is used as a binder in pyrotechnic compositions (Wikipedia, 2007).

1.13.4- Cosmetics

Spreading properties of gums add smoothness to the skin and forms a thin protective coating. They are used for preparation of facial masks, foam stabilizer, production of liquid soaps, lotions, protective creams, face powder, tooth paste, mouth wash and hair cream (Coppen, 1995 ; FAO, 2007). Gum arabic serves as an emulsifier and stabilizer in cosmetic products containing oil-water interfaces (Dror, 2006).

1.13.5- Food industry

Gums are principal components in food. The world market for gum only as food additives is over US \$ 10 billion in 1993. *Acacia* gum is usually used to modify the physical properties of foods.

The intake of low concentrations of hydrophilic polysaccharides such as

gum is beneficial as it will increase the bulk of intestinal content and also prevent excessive absorption of fats. Gums have been used in food industry in various ways (Howes, 1949).

The major functions of gum in the food products are gelling and thickening. As gums are water soluble or water dispersible hydrocolloids, they usually possess suspending, dispersing and stabilizing properties and therefore, act as emulsifiers, coagulants, adhesives, binding, bulking, encapsulating, flocculating, gelling, suspending, clarifying, swelling, thickening and whipping agents, crystallization inhibitors, film formers, stabilizers and protective colloids (Coppen, 1995; FAO,2007).

In the past, food manufacturers used gum arabic as a traditional carrier for spray dried flavor applications (Fennema, 1996). Gum arabic is one of the most commonly used food hydrocolloids and there are standards of purity for food grade gum arabic. It serves as a very efficient emulsifier and a long-term stabilizer in food (Anderson *et.al.*, 1990; Dror, 2006). As a food additive, it is a useful if rather expensive hydrocolloid emulsifier, widely used in the drinks industry to stabilize flavors and essential oils. The simultaneous presence of hydrophilic carbohydrate and hydrophobic protein enables its emulsification and stabilization properties (Chaplin, 2007).

The gum Arabic glycoprotein possesses a flexible but compact conformation. It has been suggested that the arabinogalactan-protein complex is apparently the component responsible for the emulsifying and stabilizing properties of the gum Arabic. The suggestion is based on indications that in oil droplets in emulsions, the adsorbed portion is mainly composed of the high molecular fraction (Randall *et.al.*, 1988).

Gum arabic recommended as a lubricant and binder in snack cereals, at levels from 2-5%. At 15-40% levels, it provides adhesion of dry flavours in peanuts and similar products. In low fat cake and muffin mixes, it

functions as a partial oil replacer as well as peanuts and similar as a moisture binder (Fennema, 1996).

1.13.6- Flavour fixation

Dry powdered flavors are manufactured by spray drying methods, which are done usually after the oil flavours are emulsified in gum solution (FAO, 2007; Howes, 1949). Gum arabic is an ideal carrier in flavor encapsulation because of its natural emulsifying and surface-active properties, good retention of volatile flavor components, high solubility in water (up to 50%) and acid stability. Additional advantages include its bland flavor, low hygroscopicity and ability to protect flavors from oxidation. In addition to several spray dried Arabic products; gum arabic powder is ideal for creating encapsulated spray dried flavors (Fennema, 1996). Gum Arabic is preferred in citrus oil flavour.

The ratio of gum to flavour is 4: 1 (FAO, 2007).

Microencapsulation is commonly used to transform food flavours from volatile liquids to flow able powders that can be readily incorporated into dry food products such as soups and dessert mixes. Encapsulation involves spray drying an emulsion of the flavour oil which is produced using gum arabic as emulsifier (Williams *et al.*, 1998).

1.13.7- Confectionery

The gum also emulsifies and evenly distributes the lipid compounds and gives a clear and finer taste. Gum also acts as adhesive, whipping and stabilizing agents for confections. A large part of gum arabic is used in confectionery products to prevent crystallization (Coppin, 1995; FAO, 2007; Howes, 1949).

Gum arabic prevents sucrose crystallization in gum drops, emulsifies and distributes fatty components in confections; it emulsifies and distributes fat particles in caramel and toffee. It functions as a binder and structure

builder in cough drops and lozenges. In panned sugar confections, it serves as a coating agent and film-former (Fennema, 1996).

The major application of gum arabic is in the confectionery industry where it is used in a variety of products including gums, pastilles, marshmallows and toffees. The traditional wine gums incorporated gum Arabic at concentrations of 40–55% and wine was used to add flavour. During the preparation the gum is dissolved in water keeping the temperature as low as possible (~60°C) in order to avoid precipitation of the proteinaceous components which would give rise to a turbid solution. The gum is then added to a pre-boiled sugar/glucose solution (70%) followed by the flavourings and colours. After standing to allow air bubbles to rise, any surface scum is removed and the liquid deposited into starch trays which are placed in a room for 4–6 days. The gums are then taken from the moulds, brushed to remove starch and often glazed with oil or wax. Softer gums or pastilles can be obtained by reducing the time to 2–3 days. In marshmallows the gum is used as a foam stabilizer while in toffees it is used to emulsify the fats present. Gum arabic is also used to form a glaze on coated nuts and similar products (Williams, 1998).

1.13.8- Dietetic food

Gum is used for the preparation of special purpose food (for diabetics). A mixture of gum arabic and xanthan gum is used in making low caloric products (FAO, 2007; Howes, 1949).

Gum arabic has been used in dietetic foods as a noncaloric bulking agent and has been used in the preparation of special-purpose foods such as those for diabetics. A mixture of gum arabic and xanthan (10%) has been used in the preparation of stabilized whipped or aerated low-calorie products such as butter, margarine, toppings, spreads and frozen desserts (Jumbo, 2005).

1.13.9- Bakery products

Gums give the good water holding capacity and less flabby appearance for the products. The gum gives softer and better texture and also used as a component in topping, icing bases and flavour release at specific melting temperature (Coppen, 1995; FAO, 2007). Gum arabic used as a source of soluble dietary fiber in bakery products (Fennema, 1996).

1.13.10- Beverages

Gums have been generally used as emulsifier in many beverages. They stabilize pulp in concentrates and finished drinks. Gums are also used in dry beverages, manufacturing of beer and wine clarification (FAO, 2007). Gum arabic used as a source of soluble dietary fiber in beverage (Fennema, 1996).

Gum arabic is an important ingredient in soft drink syrups, which leads to increased fizzing in carbonated beverages (Wikipedia, 2007). There is an “emulsion grade” for gum arabic to be used as emulsifiers in beverages. Significant amounts of gum are needed to stabilize cola emulsions; somewhere between 18 and 22% weight/volume (Blanshard *et al.*, 1980). Gum arabic is stable in acid conditions and is widely used as an emulsifier in the production of concentrated citrus and cola flavour oils for application in soft drinks. The gum is able to inhibit flocculation and coalescence of the oil droplets over several months and furthermore the emulsions remain stable for up to a year when diluted up to 500 times with sweetened carbonated water prior to bottling. In the preparation of the emulsion a weighting agent is normally added to the oil in order to increase the density to match that of the final beverage and thus inhibit creaming. The emulsion is prepared by adding the oil to the gum arabic

solution under high speed mixing followed by homogenization (Williams *et al.*, 1998).

1.13.11- Petroleum and gas industry

Gum is used as a component in drilling fluids, removing calcareous deposits, acidizing wells and secondary recovery of oils (Wikipedia, 2007).

1.13.12- Medicinal

Gum arabic is used for soothing mucous membranes of the intestine and to treat inflamed skin. It is also reportedly used as for its astringent properties, to treat bleeding, bronchitis, diarrhea, gonorrhea, leprosy, typhoid fever and upper respiratory tract infections (Wyk *et al.*, 2005). Gum arabic has been claimed to act as an anti-oxidant and nephroprotectant and to protect against renal, hepatic and cardiac toxicities. Gum arabic ingestion can reduce plasma cholesterol concentrations. Gum arabic has antimicrobial activity suggesting a possible use in dentistry and has an adverse effect on electrolyte balance and vitamin D. Gum arabic has been reported to be used internally for the treatment of inflammation of the intestinal mucosa, and externally to cover inflamed surfaces. It helps to reduce urea and creatinine plasma concentrations and reduces the need for dialysis from 3 to 2 times per week (Ali, 2009). It was used in a clinical study of cholesterol reduction at a dose of 15 g per day (Wolters *et al.*, 2011).

1.14- Ion exchange chromatography

Ion exchange chromatography is an exchange of ions between two electrolytes or between an electrolyte solution and complex. In most cases the term is used to denote the processes of purification, separation,

and decontamination of aqueous and other ion containing solution with solid polymeric or mineralic "ion exchange".

Typical ion exchange is ion exchange resins (Functionalized porous or gel polymer), zeolites, montmorillonite, clay, and soil humus. Ion exchange is either cation exchangers that exchange positively charged ions (cations) or anion exchanger that exchange negatively charged ions (anions). There are also amphotric exchangers that are able to exchange cations and anions simultaneously. However, the simultaneously exchange of cations and anions can be more efficiently performed in mixed beds that contain a mixture of anion and cation exchange resins, or passing the treated solution through several different ion exchange material (Dorgner, 1991).

2- Materials and Methods

2.1- Materials

Authenticated *A .polyacantha* gum were donated by Khartoum Gum Arabic Processing Company.

2.2- Preparation of samples

Gum nodules were hand cleaned to insure freedom from sand, dust and bark impurities, then ground using a mortar and pestle, and backed in labeled polyethylene bags.

2.3- Preparation of solutions

A 10% solution of *Acacia polyacantha* gum was prepared by adding 100 g of dried powder gum Arabic to 750ml of distilled water and stirred mechanically until the gum dissolved completely, the volume was completed to 1000 ml in a volumetric flask.

2.4- Preparation of glucuronic acid

Glucuronic acid was prepared using ion exchange column chromatography, where a glass column was backed with an amberlite resin IR 120 H⁺. 10% gum solution was prepared. After the sample was completely dissolved, the solution was left until it became free from bubbles and insoluble matter. The solution was passed slowly through the column and the free glucuronic acid was collected. The column was regenerated by washing with 10% solution of hydrochloric acid followed by deionized water until it became free from chloride ion (Adams *et. al.*,1977).

2.5- Preparation of glucuronates salts

Glucuronates were prepared by ion exchange method using column chromatography. the salts solutions (IM) of potassium, calcium, magnesium, and sodium chloride was prepared. The prepared solutions

was passed through the column until it was saturated by cations, followed by deionized water until it became free from chloride ion. 10% glucuronic acid solution was passed slowly through the column in its salts form, the collected eluent was glucuronates.

The solution of glucuronic acid and glucuronates were using freeze dryer (Modoulo; Edwards England); (Schleif *et. al.*,1951). The samples were dried through evaporation under high pressure. The moisture removed from samples under vacuum without passing through a liquid stage (sublimation) the temperature used from – 100 to 100 C and the vacuum range was from -10 to 5 atm.

2.6- Physico-chemical properties:

2.6.1- Moisture content

The determination was conducted according to AOAC (1990). Crucibles were dried in oven at 105 °C for 30 minutes, cooled in a desiccator and then weighed (M_1). One grams of sample were placed in the crucible and weighed accurately (M_2). Contents were heated in an oven for 5 hours at 105 °C cooled in desiccator and reweighed (M_3). Loss percentage on drying was calculated as follows:

$$\frac{(M_2 - M_3) \times 100}{M_2 - M_1}$$

Where:

M_1 : Weight of the empty crucible

M_2 : Weight of crucible + sample

M_3 : Weight of crucible + sample after drying

2.6.2- Total ash

Total ash was determined according to AOAC (1990). Crucibles were heated in an oven for 30 minutes cooled in a desiccator and then weighed (W1). About two grams of sample were placed in the crucible and accurately weighed (W2), then ignited at 550°C in a electronic muffle furnace for 2 hours, cooled in a desiccater and weighed (W3). Total ash% was calculated as follows:

$$\frac{(W_3 - W_1) \times 100}{(W_2 - W_1)}$$

Where:

W1: Weight of the empty crucible

W2: Weight of crucible + sample

W3: Weight of crucible + sample after drying

2.6.3- pH measurement

The pH value was determined for 1% aqueous solution of samples at room temperature, using a Jenway pH meter 3510.

2.6.4- Specific optical rotation

The specific optical rotation was determined according to FAO (1991). A 1.0% solution (on dry weight basis) was prepared and filtered to be highly pure. Optical rotation was measured using an optical activity Polarimeter, the tube filled with the test solution, at room temperature specific optical rotation was calculated(Omer, 2015).

$$\text{Specific rotation } [\alpha] = \frac{\alpha \times 100}{C \times L} \text{ dm}^{-1} \text{mLg}^{-1}$$

Where:

α = observed optical rotation

C = concentration of the solution (g/ml)

L = length of the Polari meter tube(dm)

2.6.5- Intrinsic viscosity

1% of glucuronic acid and gucuronates salts solution prepared using 1M NaCl as solvent, each gum solution was diluted several times and left for 30 minutes to reach thermostat temperature, then flow time was measured using U- tube viscometer for each concentration in triplicate. Finally the flow time for pure solvent (1M NaCl) was measured.

The relative viscosity was then calculated using the following equation:

Relative viscosity

$$\eta_{rel} = \frac{\eta}{\eta_o} = \frac{t}{t_o}$$

η : solution viscosity

η_o : solvent viscosity

t: flow time of solution

t_o : flow time of solvent

Specific viscosity

$$\eta_{sp} = \frac{\eta - \eta_o}{\eta_o} = \frac{t - t_o}{t_o} = \eta_{rel} - 1$$

Reduced viscosity

$$\eta_{red} = \frac{\eta_{sp}}{C} = \frac{\eta_{rel} - 1}{C}$$

inherent viscosity

$$\eta_{inh} = \frac{\ln \eta_{rel}}{C}$$

intrinsic viscosity

$$\lim_{c \rightarrow 0} \frac{\eta_{sp}}{c} = (\eta_{inh} c) = 0$$

The reduced viscosity was determined for Different concentration of samples solution 0.04,0.06, 0.08, 0.10, and 0.12g /ml and was then calculated from the above equation. The intrinsic viscosity was determined by extrapolation of reduced viscosity against concentrations back to zero concentration. The interception on Y-axis gives the intrinsic viscosity.

2.7- Determination of minerals composition

Dry ashing method was used in sample preparation, one gram of gum sample were placed in a well- glazed porcelain dish. Start in a cold furnace, and then heated to 550 °C, maintain temperature for 4 hours, cool the sample and add 10 ml of 3N HCl, cover with watch glass, and boil sample gently for 10 minute. Cool, filter into a 100 ml volumetric flask, and dilute to volume with deionized water then the element were determined using AAs.

3- Results and Discussion

3.1 - The physicochemical properties

The physicochemical properties studies which included the determination of moisture content, total ash, pH, specific rotation, intrinsic viscosity, and cationic composition were done for samples of polyacantha gum, glucuronic acid, and glucuronates salts of sodium, potassium, calcium, magnesium and iron.

Moisture content of *A. polyacantha* gum was found to be 9.13 that closer to mean value of 8.2% reported by Omer (2004).

Ash content of *A. polyacantha* gum, which was found to be 3.51%. result obtained was within the range 1.9-3.9% reported by Omer (2004).

The pH of *A. polyacantha* gum aqueous solution (1%), which was found to be 4.18, the result obtained within the range 4.1 - 5.3 that reported by Omer (2004), and in the range obtained by Siddig (2003), which was reported 4.9 for pH of *A. polyacantha* gum.

The optical rotation of *A. polyacantha* gum, which was found to be -23° , within the range of the results of Omer (2004), who reported range of optical rotation -13.5 to -26.0 specific rotation for *A. polyacantha* gum, but were higher than the values of -10.3° and -7 to -13° given by Biswas (2000) and Siddig (2003), respectively.

Viscosity or the “thickness” of a solution that a gum forms with water is of paramount importance in determining the quality or commercial value of a gum. The higher the viscosity the better is the gum (Howes, 1949). The intrinsic viscosity for *A. polyacantha* gum sample was calculated from graphical representation of the reduced viscosities and the corresponding solution concentration, which is the zero concentration

limit (De Rosa, 2008). From Figure 3.1, The value of intrinsic viscosity for *A. polyacantha* gum was found to be 12.88 ml/g, there are slight variation than intrinsic viscosity reported by Omer (2004).

The equivalent weight was found to be 1325.11 Da, This value is relatively similar to the result 1367.46 Da for *A. polyacantha* gum samples obtained by Omer (2004).

Mineral content is a measure of the amount of specific inorganic components present within a sample.

Sodium and Iron contents of *A. polyacantha* gum sample were found to be 53.35 and 24.30 µg/g which were in the ranged reported by Omer(2004).

Potassium, Calcium and Magnesium contents of *A. polyacantha* gum sample were found to be 40.69, 106.84 and 37.01 µg/g which were higher than the ranged reported by Omer (2004).

Table 3.1 Physicochemical properties of *A.polyacantha* gum sample.

Property	<i>Acacia polyacantha</i> gum (This study)	<i>Acacia polyacantha</i> gum (Omer, 2004)
Moisture %	9.13	5.8-10.6
Ash %	3.51	1.9-3.9
pH	4.18	4.1-5.3
Optical Rotation	-23.7°	-8.5 ⁰ to -26 ⁰
Intrinsic viscosity (ml/g)	12.88	10.1-10.6
Equivalent weight	1345.11	903.61-201.42

Table 3.2: The cationic compositions of *A. polyacantha* gum ($\mu\text{g/g}$)

Mineral	<i>Acacia polyacantha</i> gum (This study)	<i>Acacia polyacantha</i> gum (Omer, 2004)
Fe	24.30	21.35- 44.15
K	40.69	0.181- 0.561
Na	53.35	54.25- 33.65
Ca	106.84	0.451- 2.165
Mg	37.01	0.047-2.398

3.2- Properties of prepared glucuronic acid and glucuronates salts

Table 3.2 show the moisture content of glucuronic acid and glucuronates, Increase of moisture content of glucuronic acid and glucuronates salts compared with samples of *A. polyacantha* refer to the The efficiency of the freeze drying process that dependent upon the surface area and the thickness of the sample, the collector temperature and vacuum obtained, the eutectic point and solute concentration of the sample.

Table 3.2 show the total ash, the Lower percentage of ash for glucuronic acid indicate to removal of most mineral contained in gum sample, that refer to efficiency of ion exchange. For other samples the values were found to be greater than value of glucuronic acid, that confirm the ion exchange was happened and the glucuronic acid converted to glucuronates salts for a mineral. There are significant difference between ash value of glucuronate salt, that due to the atomic weight of metals and valency of an elements of a mineral that constructed glucuronates salts. Glucuronic acid show typical acid behaves with low pH, that confirm the metallic ion exchange by hydrogen ion.

as shown in table 3.2 , Na, K, Ca, Mg, Fe glucuronates pH were in close pH range, the pH of glucuronate was higher values than glucuronic acid that also refer to ion exchange happened, the hydrogen ion removed from glucuronic acid by metallic ion.

Glucuronates of Na, K, Ca, Mg and Fe show significant variation in the pH from parent gum, that due to presence of some traces of glucuronic acid in salts.

Table 3.3, shows the optical rotation for (0.1M) aqueous solutions for each sample. All samples were found to be optically active (laevorotatory).

Table 3.1 and Figure 3.1 show the intrinsic viscosity of *A. polyacantha* gum, glucuronic acid and glucuronates in 1M NaCl. The results show all glucuronates except iron glucronate have smaller viscosities than the glucuronic acid and the parent gum. It was observe the viscosity of glucuronic acid solution is decreased with the addition of metal ions and it was further decrease with increasing concentration of NaCl. Suppression of charge by the colloidal particles of the solution may give explanation for the decrease in viscosity. The results are in good agreement with those reported by Zulfa (2014).

The results of mineral content of glucuronic acid show lower concentration of mineral, that illustrate the succession prepared of glucuronic acid.

The mineral contents of glucuronates salts show high concentration for respective cation of glucuronates salts that confirm the preparation of glucuronates salts.

Table 3.3 physicochemical properties of glucuronic acid and glucuronate salts

Sample	Moisture %	Ash %	pH	Optical rotation	Intrinsic viscosity (ml/g)
glucuronic acid	12.69	0.43	3.08	-29.0°	9.29
Na glucuronate	12.45	2.34	3.80	-14.2°	7.90
K glucuronate	11.52	3.02	3.87	-17.5°	5.21
Ca glucuronate	12.38	2.43	3.54	-17.2°	6.17
Mg glucuronate	13.44	1.50	3.63	-15.0°	7.31
Fe glucuronate	11.27	2.53	3.49	-15.3°	9.29

3.3- Mineral analysis

Table 3.3: Mineral contents of *Acacia polyacantha*, glucuronic acid and glucuronate ($\mu\text{g/g}$).

samples	Fe	K	Na	Ca	Mg
<i>Acacia polyacantha</i> gum	24.30	40.69	53.35	106.84	37.01
glucuronic acid	1.66	1.92	4.98	10.34	9.46
Feglucuronate	223	-	-	-	-
Mg glucuronate	-	-	-	-	112
Ca glucuronate	-	-	-	184	-
K glucuronate	-	239	-	-	-
Na glucuronate	-	-	191	-	-

(-) Absent.

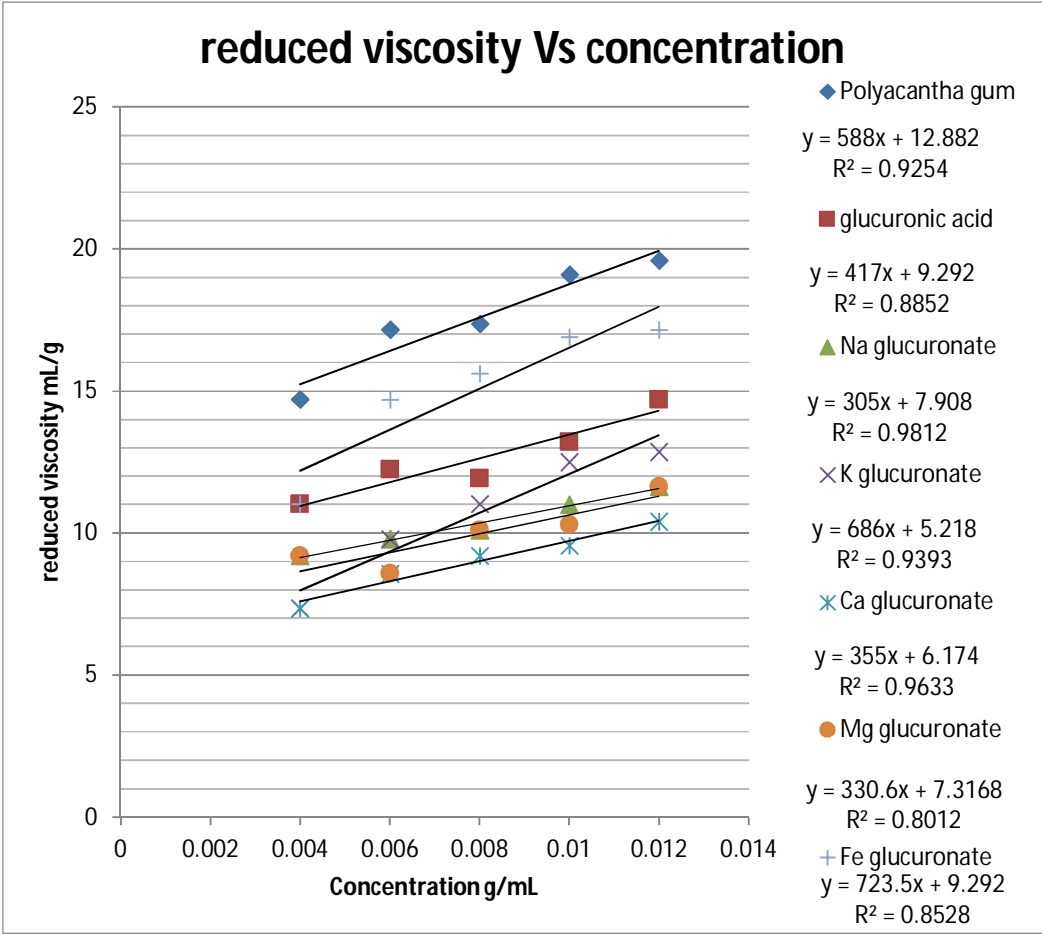


Figure 3.1: Reduced viscosities of raw gum, glucuronic acid and glucuronates salts

Conclusion:

On the basis of results obtained, it could be concluded that:

1. This work mainly involve the preparation of glucuronic acid and glucuronates salts from the *Acacia polyacantha*, From the obtained results the study succeeded in preparing them using ion exchange chromatography method.
2. The results showed that the change of metal elements of the gum cause changes in the physical properties of the gums such as pH intrinsic viscosity.
3. The results showed the similarities between the properties of gum studied and results from previous researches, which indicate that the gum under study is an authentic *Acacia polyacantha* gum.
4. The cationic composition study shows that calcium has highest value followed by sodium, potassium, magnesium and iron.

Recommendations:

1. Further details of structural study should be carried out on the glucuronate salts and glucuronic acid.
2. Further research efforts should be directed to study emulsifying property of glucuronats salts compared with parent gum.
3. The gum has high concentration of essential minerals content as iron, so that it can be used for nutritive values.

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