Chapter One

1.1 Introduction

Plant gums are generally the exudates from various plants formed as protection mechanism to cover wounds on the bark of trees to prevent attack by micro-organisms shortly after injury (Mantell, 1965) these exudates are usually viscous fluids that ooze on the surface of the tree's bark at the point of injury and gradually dry to hard glassy nodules. Plant gums are safe for use as pharmaceutical substances and food additives apart from various industrial applications. Natural gums are incorporated in a very diverse range of food formulations to impart avid variety of characterises to the food products. Thus, gums are used as stabilizing, suspending, gelling, emulsifying, thickening, binding and coating agents. Further, many plant gums have been modified in order to improve the properties for application as matrix for controlled drug delivery, tissue reconstruction, pH and electrical sensitive hydrogels and also to remove heavy metals from effluents, (Verbeken , *et al.*, 2003). Gums are hydrophilic carbohydrate polymers of high molecular weight, generally composed of monosaccharide units joined by glycosidic bonds. Natural gums are of plant origin and are found either in the intracellular parts of the plant or as extracellular exudates, produced as a result of injury to the plant. At the site of injury, as a defense mechanism an aqueous gum solution is exuded to seal

the wound, preventing the infection and dehydration of the plant. These exudates dry on contact with air and sunlight to form hard lumps that can be easily collected (Silva, *et al.*, 2006). Gums are a class of substances organic in nature and related to sugars and carbohydrates. They are uncrystallizable and are usually composed of carbon, hydrogen and oxygen. Gums have the characteristic property of forming viscous solutions and mucilage either by dissolving in water or absorbing their own volume of water .Gums are colloids, amorphous , hydrophilic and organic – solvent phobic (Awouda 1973). Gums are polyuronides, containing D-glucuronic acid residues. In addition, hexoses, pentoses and methylpentoses have been isolated from different gum hydrolysates. Some gums contain acidic components and others are neutral.

1.2 The aims of this work .

-To characterize *Albizia amara* gum by studying the physicochemical properties.

-To compare and contrast the physicochemical properties of the gums under investigation and with each other.

-To study, comparatively the emulsion stability properties and antioxidant activity.

-To investigate the thermodynamic properties of the gum solution**.**

Chapter Two

2.1 Plant gum.

Plant gums are high molecular weight polymeric compounds, composed mainly of polysaccharides capable of possessing colloidal properties in appropriate solvents (Glicksman, 1973).

Gums are either hydrophobic or hydrophilic. Hydrophobic gums are insoluble in water and include resins, rubber …ect. Where as hydrophilic gums are soluble in water and can be subdivided into natural, semi synthetic and synthetic gums (Glicksman, 1973).Natural gums are those derived from plant and animals. Natural gums of plant origin seem to be associated with plant life processes. Formation of plant gums natural gummy exudates, occurs when the tree is in an unhealthy condition (Meer, *et al.,* 1980) as a result of evaporation on the surface of soft droplet –like tears and diffusion of the aqueous portion from the inside to the outside of the tear. One particular aspect, which is imperfectly understood, is the extent to which micro-organisms are active in producing trees, and whether the gum itself is formed to prevent such bacterial infection or is a result of that infection; but some explain the formation of gums as a defense mechanism to seal off the wounds caused by insects or micro-organisms to prevent desiccation (Blunt, H.S.I 1926)

2.2 The gum belt

The gum belt refers to a broad band , situated at a latitude of between 4^{o} and 16^{o} north , stretching across sub – Saharan Africa from Mauritania in the west , through Senegal and Mali , Burkina Faso ,Niger north Nigeria to Sudan , Eritrea, Ethiopia, Kenya, Somalia and northern Uganda in the east. Most of these countries appear in the statistics as sources of gums, although they differ greatly in terms of the quantities involved (A. A. Satti 2011).

2.3. Acacia gums

The gum exuded from species of the genus *Acacia* have been important commercial material since ancient times. the genus *Acacia* is one of the largest and most complex in the plant kingdom and botanical specialists agree that 1000 different *Acacia* species have been identified (Kordofani, 1989) of the 90 *Acacia* species studied to date, some are rare and others do not yield gum sufficiently copiously to be of poor solubility, poor colour and astringent taste and therefore appear to be of little possible commercial interest. At the present time, it appears that *Acacia Senegal* willd (syn verek) is the source of 80% the *Acacia* gum, commercially, marketed with the *Acacia seyal* and members of its complex providing some 10%: while others probably contribute the balance (D.M.W Anderson 1977) .The origin of plant gum is still uncertain, but some authorities believed it to be the starch granules present in the cell. They are extremely complex polysaccharide and occur naturally as salts specially of Ca,

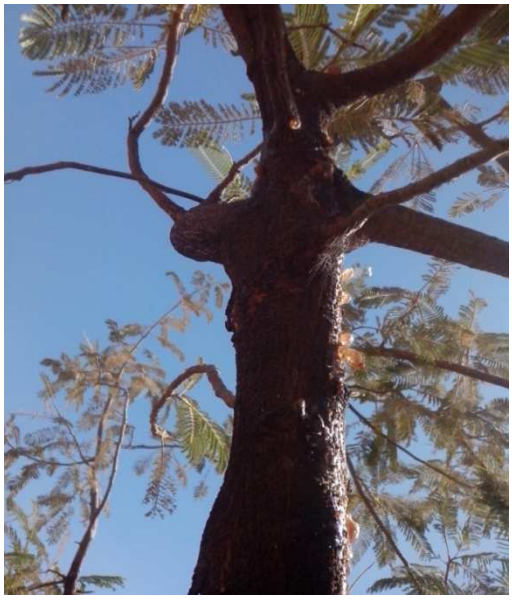
Mg and in some cases a proportion of hydroxyl groups are acetylated or methylated (Aspinal 1970).

The species had a wide distribution and a remarkable adaptability. They are, essentially, semi-arid zone species tolerant to drought .They are native to areas having between 100-800mm rain falls with dry season lasting more than 10 months. In general, areas which produce good quality gums are those with poor rain fall, hot temperature and low soil- salt. Commercial production of gum is restricted to certain zones and almost all of it is produced in Africa north of the equator (E.H. Abdelkarim 1992).

2.4 Non Acacia gums in Sudan

Other, gum yielding, species widely distributed in Sudan is *Albizia amara* , *Boswllia papyrifera* etc: , B.papyrifera is the source of frankincense or gum olibanum grows, naturally, on the rocky ground of the hilly parts of central Sudan, Blue Nile (jebel Garri), Kordofanian (Nuba mountains), Darfur (Zalingei . Jebel Marra).It is used widely as incense in the holly place and temples, (H.M. Elamin, 1990).

2.5 Botanical classification of *Albizia amara*



synonyms

Afrikaans: bitter valsdoring

Arabic: arrad,

English: bitter albizia

2.5 .1 Scientific classification

Current name: *Albizia amara*

Authority: Boivin

Family*:* *Leguminosae*

Sub-family*:* *Mimosoideae*

Genus*:* *Albizia*

Species*:* *amara*

2.5.2 Description and Ecology

A deciduous tree, often rounded or spreading crown, reaching 10 m in height. Bark dark brown and, roughly, cracked. Leaves compound with numerous small leaflets, feathery. Leaves and twigs covered with distinctive soft, golden hairs. Numerous small creamy-white flowers crowded together at the ends of branches. The large pods are brown and papery, up to 20 cm by 3 cm. The species grows well at altitudes of 1,000 to 1,800 m. It is often found along dry river beds with an annual rainfall of at least 350 mm. It has a wide distribution

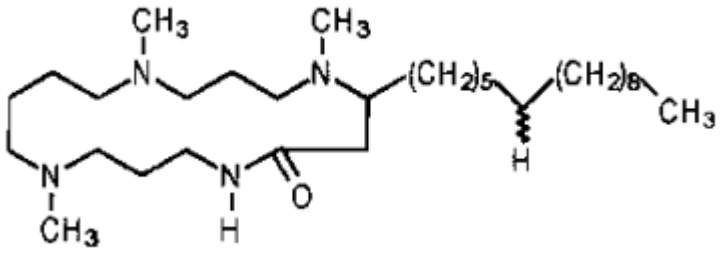
in Africa, occurring from Sudan and Ethiopia southwards to Zimbabwe, Botswana and the Transvaal, growing Mainly in sandy woodland.

2.5.3 Cultivation

Albizia amara can be propagated by direct sowing, through seedlings, cuttings and wildlings. Natural regeneration from seed is good in areas protected from fire and grazing. It grows very freely as coppice, producing a large number of shoots. Seed pre-treatment involves immersion in boiling water for 5 min followed by soaking for 12 hours. Treated seed once sown will germinate within 7 to 10 days. Germination of around 80% can be expected. Seed is orthodox in character and can be stored for 2 years or more without losing viability appreciably. Seed can be stored in mud pots with wood ash or in sealed tins or gunny bags Seedlings planted in farmland can be spaced 9 to 10 m apart along contour lines. Young seedlings should be protected from fire and grazing livestock. Coppice can be thinned when 2 to 3 m tall a year after cutting, or when 5 to 8 m tall after three or four years of growth. *Albizia amara* has been introduced in to India and Indonesia. In Kenya, Tanzania and Uganda, the species is often incorporated into smallholding farming systems with corn, cassava, maize, beans and fruit trees, such as papaya, mango and orange.

2.5.4 Uses

A valuable economic, medicinal and multipurpose drought tolerant tree, commonly, found in dry forests. The wood of *Albizia amara* is purplish brown with lighter bands, very hard and strong, used for cabinets in building and agriculture purpose. The tree yields gum, which is used for ulcers (Kashyapa 1992) and molluscidal activity (Ayoub1986). Besides these, Bark stem decoction taken three times a day serves as an emetic to induce vomiting and to treat malaria. (Dharani 2010). The leaves contain a flavanol glycoside namely 4'O–menthylrutin and they are extensively used as herbal cosmetic for hair maintenance. Leaves are also useful in ophthalmia. Budmunchiamines, spermine macrocyclic alkaloid (pezzuto, JM., *et al*., 1991) extracted from the seeds of *Albizia amara* were found to interact with DNA by inhibiting the catalytic activity of DNA polymerase, RNA Polymerase, and HIV reverse transcriptase.



Bubmunchiamine K

2.6 Production of gum in Sudan

The gum is produced in Sudan by the tapping technique which began 75 years ago (Mantell, 1973).the tree is tapped at first when it reaches a height 4-5 feet with a main stem of about 2.8 (7cm) or more in diameter. There are two tapping periods in one season ,commonly known as first and second .the first tapping process usually starts at the mid of October from each year after the rainy season and up to the mid of march and is thought to give the best yield. (Awouda , 1973). Traditionally, a small axe or Sonkee is used for tapping. Alight blow is directed to the side of the branch and paralled to it so that the blade penetrates between the bark and downwards to tear off the strip of the bark between 60-100cm in length. In the next tapping season, the opposite side of the branch is tapped (Awouda 1973).The gum appears at one or more points along the strip edges , starting as droplet- like tears which, gradually, grows in size to a nodule after a time varying from tree to tree and from one locality to aother .A first collection of gum may be made three weeks after tapping and thereafter at intervals of about two weeks or so. As soon as the nodules are picked new ones start to form and within 10-15 days a second picking is possible .An average of four pickings can be carried out in each season .after the gum has been collected, it is hand cleaned to remove fragments of bark other impurities, sorted in to grades and then spread out in the sun in thin layers for several weeks to dry. Some of bleaching goes on during the exposure of the gum to the bright sun and intense heat. The quality of the gum is judged

by its appearance and the best grade is reputed to be of tears which are transparent or almost so. Dark colour gum samples are due to the presence of tannin and have unpleasant taste(Abdelkareim, 1992).

2.7 Identification of gum varieties

Gums are recognized by their physical appearance i.e size , shape ,colour, brittleness …..etc. Gum tragacanth is an opaque whitish flakes, while gum Arabic is clear pale yellow or brownish tears which fracture readily. Gum Arabic dissolves easily in water while gum tragacanth or gum Karaya are partially water soluble, forming a more viscous solution than a solution of gum Arabic of equal concentration (Davidson, 1980). In addition the rate of settling of a precipitate formed after treatment of aqueous solution of the gums with alcohol, may also be used as preliminary test for identification (Bundesen *et al.*, 1954) .Gum Arabic separates as a curdy white precipitate. Whereas gum tragacanth produces a stringy mucilaginous precipitate (Sullivan 1901).Preliminary test also includes measurements of specific optical rotation. The recent technique of infra-red analysis proved to be useful since the various sugar components and glycoside linkages can often be distinguished.

2.8 Physical Aspects of gum

The physical Aspects of gum, established as quality parameters include moisture, total ash, volatile matter and internal energy. Gum is a natural product complex mixture of hydrophilic carbohydrate and hydrophobic

protein components (FAO, 1990). Hydrophobic protein component functions as an emulsifier which adsorbs onto surface of oil droplets while hydrophilic carbohydrate component inhibits flocculation and coalescence of molecules through electrostatic and steric repulsions (Anderson and Weiping, 1990). Moisture content facilitates the solubility of hydrophilic carbohydrates and hydrophobic proteins in gum (Elmqvist, 2003). Total ash content is used to determine the critical levels of foreign matter, acid insoluble matter, and Cations (Mocak *et al*., 1998). The cationic compositions of ash content are used to determine the specific levels of heavy metals in quality of gum (FAO, 1990, 1996). Volatile matter of gum determines the characteristics and the degree of polymerization contained in sugar compositions (arabinose, galactose and rhamnose).Sugar gums which exhibits strong emulsifying properties functioning as binders and stabilisers in the making of cough syrups in pharmaceutical industry (Phillips and Williams, 2001; Philips et al., 2006). Optical rotation is used to determine the nature of sugars in gum. The specifications state that the best quality of gum for *Acacia senegal*var. *senegal*. must have negative optical rotation with the range of -26° to -34° (Table 2.1). Nitrogen content in gum determines the number of amino acid and protein content compositions with the range of 0.26 to 0.39% (FAO, 1990). Gum is used as an emulsifier and stabilizer in the food and pharmaceutical industries (Osman *et al*., 1993a, b). Other industrial products that use technical grades of gum include adhesives, textiles, printing,

lithography, paints, paper sizing and pottery glazing (Idris *et al*., 1998). Gum is produced from natural stands of *A. senegal* varieties in arid and semi-arid lands ecosystem of northern Kenya (Chikamai 1994; Chikamai, 1997). Gum is collected during the dry seasons by herdsmen and women groups from different botanical sources. The harvested gums are mixed and sold to middle businessmen in local trading centres who export them without standard quality control to world market (Chikamai 1994).

Table(2.1) International specification of quality parameters of gum Arabic*

Property	Range
Moisture content (%)	13-15
Ash content (%)	2-4
Internal energy (%)	30-39
Volatile matter (%)	51-65
Optical rotation (degrees)	(-26) - (-34)
Nitrogen content (%)	0.26- 0.39
Cationic composition of total ash (550^{o}C	ppm
Copper	52-66
Iron	730-2490
Manganese	69-117
Zinc	45-11

Source of gum: Kordofanian gum belt region, Sudan. Species: *A. senegal* var. *Senegal* And its varieties. *Ref:FAO(1990)

2.9 Gum collection in Sudan.

Gum Hashab is collected from *Acacia senegal* by tapping, anther hand all gums talha from *Asyal* and *Abizia amara* is collected as a result of natural exudation. Tapping begins when the trees are just starting to shed their leaves, around the end of October or the beginning of November. In order to reach this stage, trees have to grow for a period of 3 to 7 years. Again in the Sudan, there are two tapping seasons, an earlier one before the onset of the colder weather

which is between the months of December and March and a later one in the dry spell after March. After tapping, exudation occurs gradually forming a hard but slightly elastic nodule. As more gum exudes the outer skin expands and the nodule grows to about 15-30 mm in diameter. When the outer casing becomes so hard that the liquid cannot force it to expand any further, the nodule is ready for picking. The time taken to reach this stage is from 3-6 weeks and as soon as the nodules are picked, new ones start to form and within 10-15 days a second picking is possible. Several branches are treated in this manner at one tapping. In the following years, other branches or the reverse side of the same treated branches are tapped. An average of four pickings is common, up to seven. The nodules are picked by hand and placed in general in a basket carried by the collector (MNP, 1980).

2.10 **Processing of gums**

Cleaning is a process, which is done before undergoing any further process.

Cleaning involves the removal of sand, fines (small fragment of gum) and bark.

2.10.1 Kibbling

It is the pulverization of gum into small fragments. The fragments of kibbled gum are 0.5 – 2 cm in size.

2.10.2 Spray-dried gum

This involves dissolving of kibbled gum, sieving it, centrifuging to remove insoluble material, pasteurization then spraying the solution into fine droplets (by atomization into a stream of hot air, 70 – 80 ^{o}C, which evaporates water) (William, 1990).

2.10.3 Roller dried gum

The gum is dissolved then coated into rollers by a flow of air. Then the dried gum film is scrapped off the roller. The final product is large flakes of gum.

2.11 Chemical Composition of Gums

2.11.1 Polysaccharides

Polysaccharides are natural macromolecules found in all living organisms; they perform many functions, some of which are not fully understood. However, one of their main functions is the constitution of the main part of the cell wall of higher plants and seaweeds. They also provide reserve food supplies in animals and plants. Polysaccharides also act as an encapsulating substance in microorganisms and as a thickening agent in joint fluids in animals. Moreover, protective gums given out by, plants to seal sites of injuries in the stem or branches are mainly polysaccharides. Naturally occurring polysaccharides contain molecules which vary in detailed structure, i.e.

Polymolecular and polydispersed, but have the same general structure (Aspinal, 1970).

2.11.2 Arabinogalactans

Arabinogalactans are polysaccharides which contain arabinose and galactose as major constituents. They represent the main polysaccharides in different plant tissues. Arabinogalactans are classified into three classes as detailed in Table (2.2). Moreover, they may be isolated as free polysaccharides or occur in covalent association with proteins either as Proteoglycans, where the protein component carries a polysaccharide constituent (Reid *et al*., 1978), or as glycoproteins, in which the protein component is covalently linked to one or more oligosaccharide residue (Marshal, 1972; Karnfeld *et al*., 1976).

The protein content of arabinogalactan-protein varies between 2 to 6%, however, values as high as 60% have been reported (Anderson *et al*., 1979; Fincher *et al*., 1983). Amino acids have long been known be involved in covalent linkages between the polysaccharide and protinacious moieties in glycoprotein and proteoglycans (Lampert, *et al*., 1967; Fincher *et al*.1983; Selvend *et al*., 1982). Hydroxyproline and serine have been found to be the most frequently encountered amino acids involved in carbohydrate-protein linkages in plant glycoproteins (Allen *et al*., 1978; Lampert *et al*., 1978; Straham *et al*., 1981). Different chromatographic methods such as hydrophobic interaction chromatography (H1C), size exclusion

chromatography (SEC) and ion exchange chromatography (IEC) have been successfully used to isolate glucopeptides. Methods such as, alkaline hydrolysis (Lampert, 1967), enzyme degradation (Hillstead *et al.*, 1977), salt precipitation and hydrazinolysis have also been used with equal success to isolate and characterize glycopeptides (Yosizawa *et al.*, 1966). Gum Arabic has been shown to be composed of six main carbohydrate components; galactopyranose, arabinopyranose, arabion-furanose, rhamnopyranose, glucopyranosyl uronic acid and 4-*O*-methyl glucopyranosyl uronic acid in addition to functionally important amount of proteins and minerals (Islam *et al*., 1997)

Table [2.2]: Classification of plant arabinogalactans. (Reid *et al.*, 1978).

Arabinoglactan	Source
Arabino-4-galactans (Aspinall Type 1)	Pectic complex in seeds, bulbs, leaves, coniferous compression wood
Arabino-3,6-galactans (Aspinall Type II)	Mosses, coniferous wood, gums, saps and exudates of angiosperms
Polysaccharide with arabinogalactan side Chain	Seeds, Leaves, roots and fruit, Gums and Pectic complexes.

2.12 Gum structure

Gums are the salt of an organic acid, with metals such as calcium, magnesium, and potassium. The hydrolysis of the gum has been shown by many authors (Hawarth *et al.,* 1931). These authors showed that gum amble consists of D-galactose, L-arabinose, L-rhamnose, and D-glucuronic acid. (Anderson, *et al*1966) and showed that a sample of *acacia senegal* gum (gum arabic) had the following approximate percentages for its various constituents: D-galactose 39%,L-arabinose 28%, L-rhamnose 14%, D-glucuronic add 17% and 4-0-methyl-D-glucronic acid 1.5% ,(Anderson *et al.,*1987). He reported that gum amble contains 2.3 to 30% of proteinaceous material (smith,1940) has shown that gum does not only consist of different monosaccharide components, but these components are joined by no less than three different types of linkages a 1,3 link between the units of gum Arabic (by the auto hydrolysis of arabic acid), which produces degraded arabic acid and a mixture of three reducing sugars.

a) 3-galactosido-L-arabinose.

b) Prolonged auto hydrolysis of the degraded arabic acid produces the disaccharide, 3-galactoside- Galactose .

c) 2,5-dimethyl-L-arabinoseis Identified as one of the hydrolysis products of methylated arabic acid.

From the hydrolytic product of methylated degraded and methylated arabic acid, the presence of 2,4-dimethyl galactose proved that 1,3 and 1.4 links are present. Smith, (1940) and Anderson *et al.,*1966) have shown that gum arabic

contains a fundamental chain of D-galactose units, exclusively involving 1,3 linkages. The presence of increased proportions of 2,4,6-tri-0-methyl-D-galactose in the methylated auto hydrolysed gum suggests that some of the residues in the chains of beta 1,3 linked galactose units are 6-0 substituted with add labile arabino- furanose units(Anderson *el at.*,1966). The isolation of 2,3-dimethyl-glucuroniac acid can suggest the presence of 1,4 links In arabic acid (Smith 1940).) The isolation and characterisation after deacetylation of 4-0-α-L-rhamnopyranoseyl-D-glucosferom acetolysis of diborane-reduced acetylated gum established that some L-rhamnopyranose residues are glycosidically Iinked to C-4 bonds of D-glucuronlc acid (Aspinall *et al.,* 1963).The 1,6-type of linkage in arabic acid has been established by the following way:

a) By the Isolation of the 6-β-glucuronosidogalactose from arabic acid.

b) By the formation of the hexamethyl 6-β-glucuronosidogalactose by graded hydrolysis of methylated arabic acid Smith(1940).

c) By the isolation of 2, 3, 4-trymethyl-galactosefrom the methylated degraded arabic acid(Smith1940).

From the above studies and others Smith (1940).proposed a possible structure for an arabic acid which may be shown in the fragment for acacia sene gal gums that structure have been degraded through seven successive Smith degradation processes(Anderson *et al*, 1966). The study of the O-methyl derivatives of each of the polysaccharide obtained from the first five degradations and the study of the methylated polysaccharides after the fifth

degradation together with the partial acid hydrolysis of the methylated polysaccharldes and the degradation of the gum by auto hydrolysis and the methylation of the autohydrolysed gum all lead to a modified structure of gum arabic, which is shown in Figure (2.1)

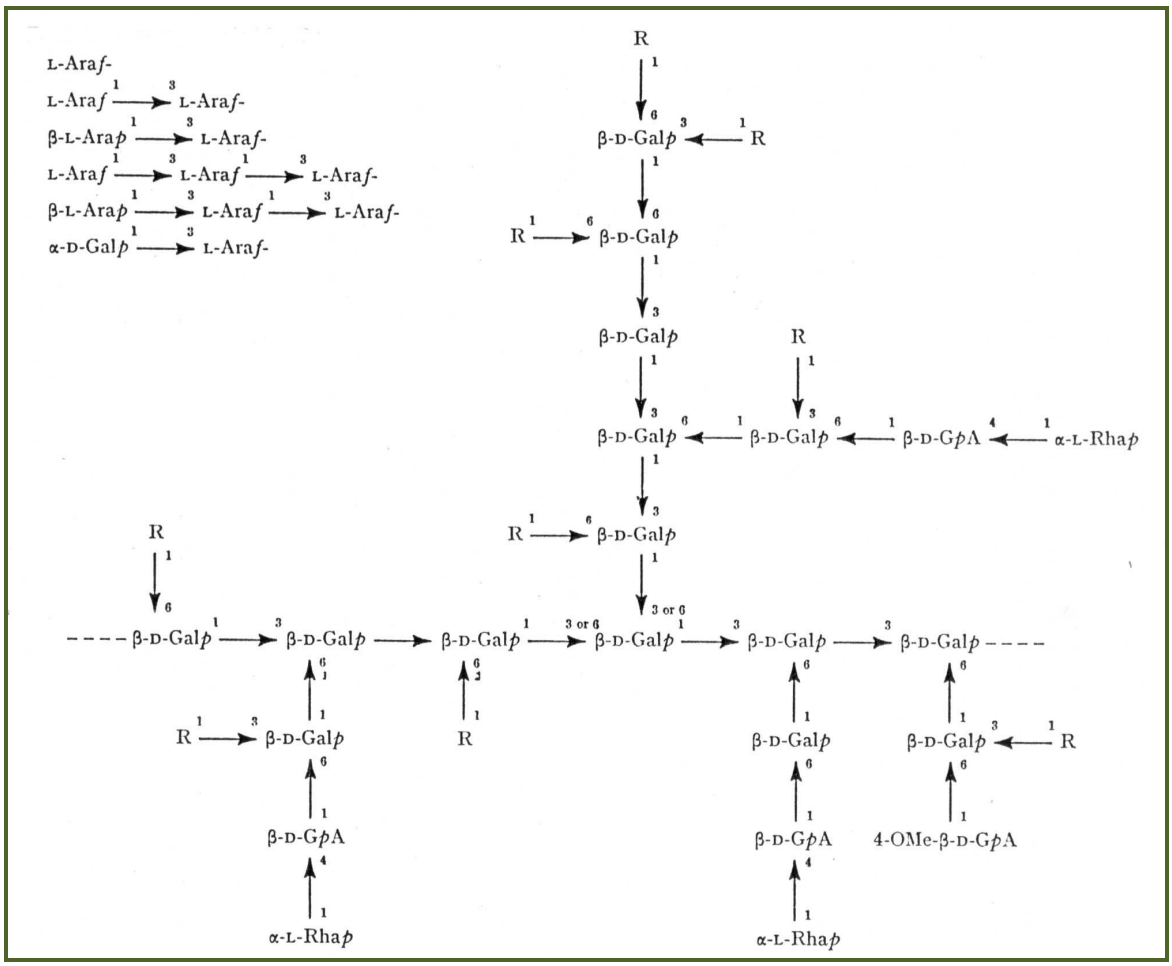
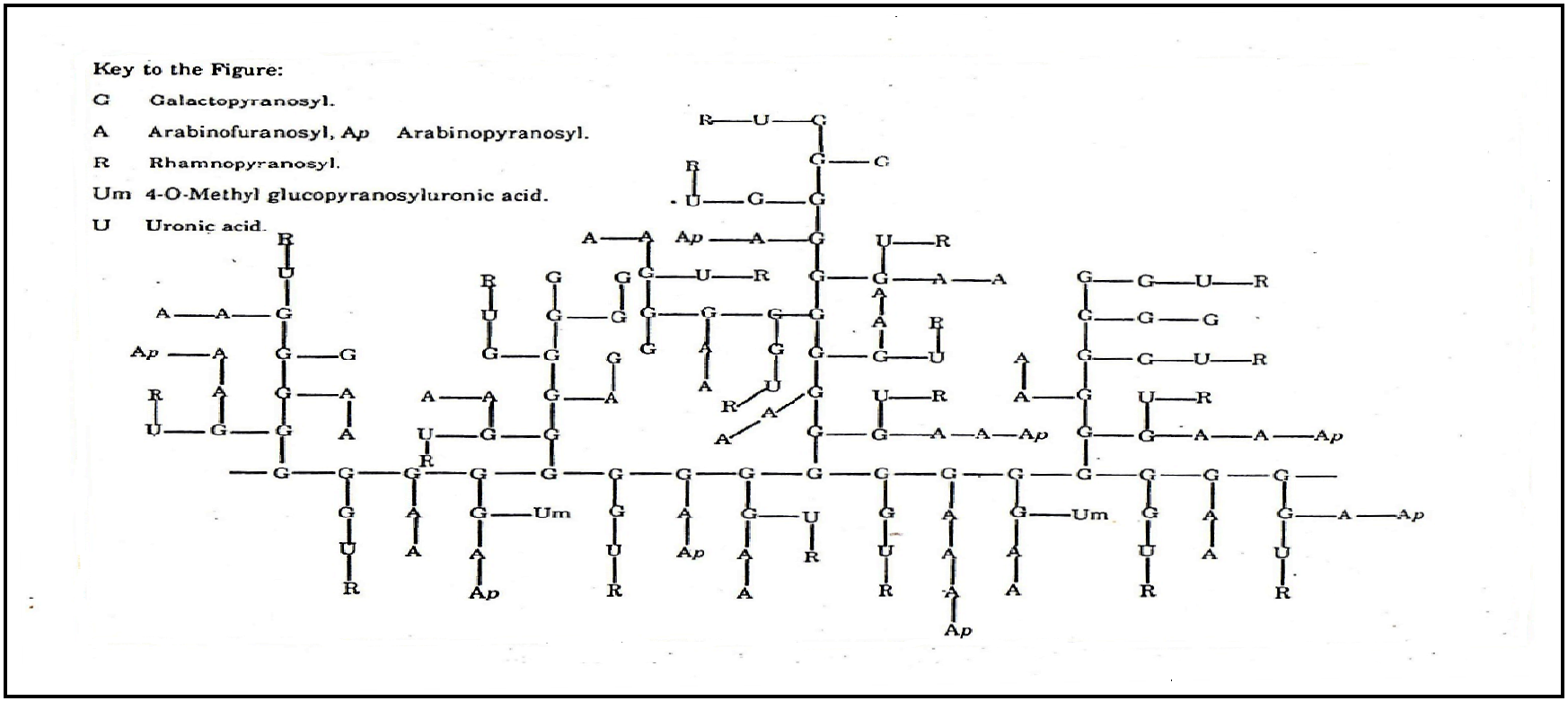


Fig (2.1): Structure Fragment for *Acacia Senegal* gums (Anderson et al, 1966)

Street and Anderson (" provide more calculations and studies on the seventh Smith degradation which were report by Anderson (1959,1966).These authors modified a model of the gum arabic molecule. This model is shown in Figure (2.2).



Figuer(2.2) the structur of senegsl (Anderson, 1983)

Gums, a natural composite polysaccharide derived from exudates of *A. senegal* and *A. seyal* trees, is one of the most commonly used food hydrocolloids. Gums serves as a very efficient emulsifier and a long-term stabilizer in food and cosmetic products containing oil-water interfaces. That Gum is recognized by many researchers that it consists of mainly three fractions, shows the structure of gums 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. 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 glucoronic acid. The smallest fraction having the highest protein content is a glycoprotein which differs in its amino acids composition as shown in Figure (2.3),(Ellis *et al*. 2010)

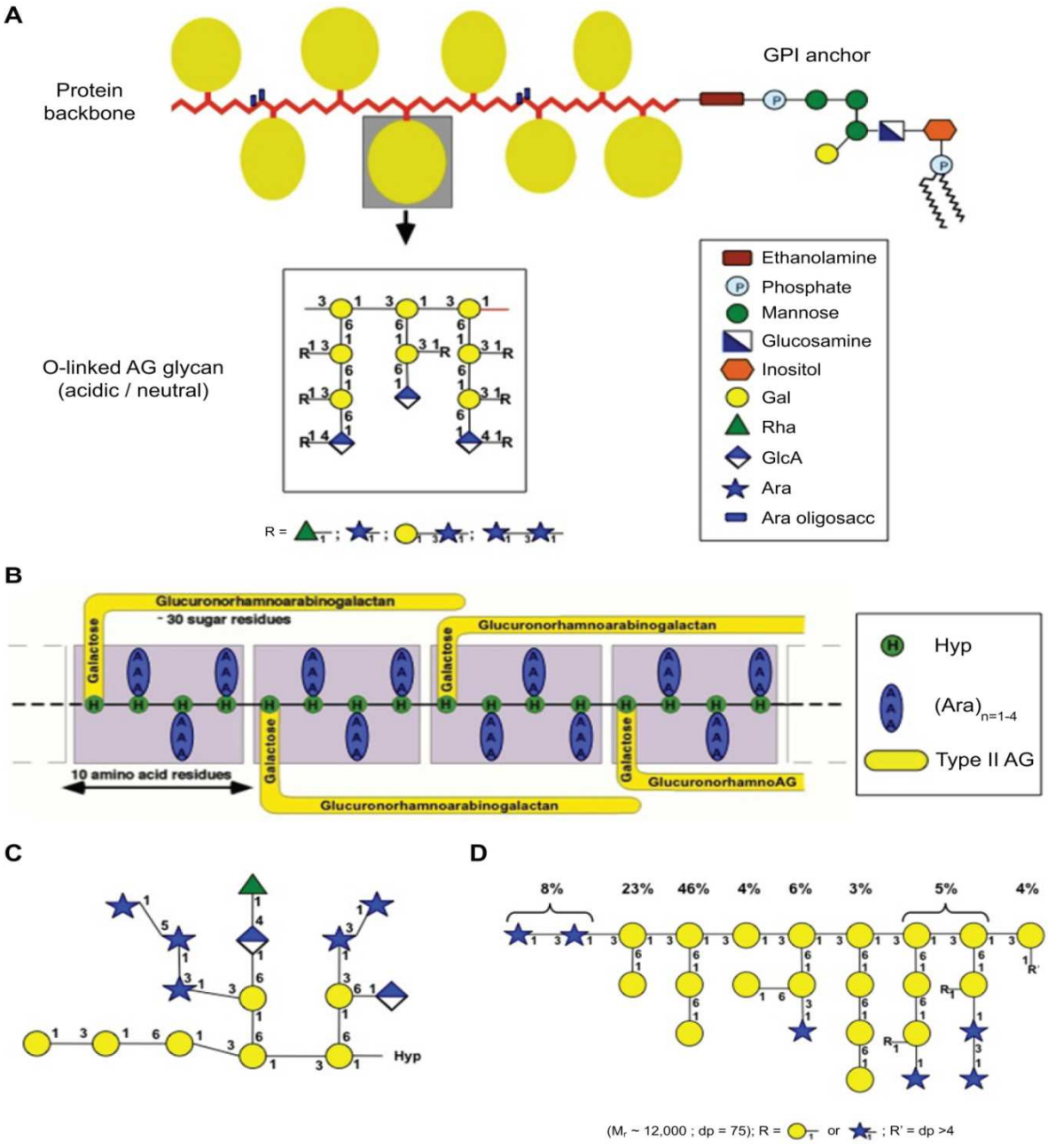


Figure (2.3) **Schematic representation of the diversity of AGP glycan structures (taken from Ellis *et al* . 2010). (A)** The“ wattle blossom” model of the structure of AGP s with a GPI-membrane anchor attached (modified from Fincheretal. 1983). **(B)** The “twisted-hairy rope” model of the structure of the Gum Arabic glyco protein (GAGP; from Qi etal., 1991). **(C)** Primary structure of are presentative Hyp – Ag polysaccharide (AHP-1) released by base hydrolysis from a synthetic AGP (Ala-Hyp) 51 from tobaccoBY2cells (modified from Tanetal. 2004). **(D)** Larch AG structure (modified from PonderandRichards, 1997).

2.13 Commercial uses of gums

The use of gums in food products depends mainly on its ability to impart desirable qualities through its influence over the viscosity, body and texture, and the ease with which it forms colloids or as stabilizer. It dissolves easily in water to form viscous solution which does not affect the color, odour or flavor of food or drug it is used in.

Gums are in the GRAS (generally recognized as safe) list under the federal Food, drug and cosmetic Act. it is listed in the .U.S pharmacopeia and food chemical codex.

With respect to human nutrition, it is generally agreed that gums has a low level of digestibility, and in food system, it will not contribute to caloric intake. Gums are rich in dietery fiber which is very beneficial for diabeties (Booth *et al.* 1949).

2.13.1 Food Applications

2.13.2 Confectioneries

Gums are used extensively in confectionery industry primarily because of its ability to prevent crystallization of sugar and of its thickening power. It is used as glaze in candy products and a component of chewing gum (Davidson 1980).

2.13.3 Dairy products

Gum is used as stabilizer in frozen products such as ice –creams, sherbets because of its water absorbing properties (Davidson 1980). Other uses include preparing packable milk or cream, or as protective colloid in the preparation of processed baby food (Walden 1949)

2.13.4 Bakery products

Because of its viscosity and adhesiveness gum is widely used in baking industry as glazes and toppings .as emulsion stabilizer it bestows smoothness when used e.g. the glaze is applied to bun while still warm which adheres firmly upon cooling.

2.13.5 Flavor fixation and emulsification:

Gum is used as fixative for flavor by forming a thin film around the flavor particles protecting it from absorbing moisture from the air. These products could last for years while non – protected material oxidized in seconds (Davidson 1980).

2.14. Other uses

2.14.1 **Pharmaceuticals**

The inherent emulsifying and stabilizing properties of gum together with its demulcent and emollient characteristics have led to a number of applications ranging from stabilization of emulsions to preparation of tablets, e.g

production of cough syrups, it produces a smooth viscous syrup and prevent crystallization of sugar in them. Gum is also as adhesive or binder for pharmaceutical tablets and in the manufacture of plasters (Andon ,1956).

It is an ingredient in diabetic syrups and various non sugar recipes e.g. non – sugar cherry syrup has been developed and its mixture with silver bromide in the form of silver arabate has antiseptic property for treatment of ophthalmic infections (Feinberg *et al*.,1940) Gum is effective in preservation of vitamin c in aqueous solutions.

2.14.2 **Medicines**

Gum has been used for treatment of low blood pressure caused by hemorrhage or surgical shock (Mytum *et al.*, 1932) the addition of 7% gum solution reduce the dissipation rate of sodium chloride solution in intravenous saline injection . In 1933 gum recommended for treatment of nephritic edema when used as intravenous injection (Merck, 1968.)

2.14.3 Cosmetics

Gum is reported free from dermatological and allergic toxicity and thus it is used in lotion and protective cream. It stabilizes emulsions increasing, adds smooth feeling to the skin and forms protective coating.

It is also used as adhesive in the preparations of facial masks (Reevies, 1951), as a binding agent in rouges, and as a foam stabilizer in the production of liquid soap (Smith, 1956)

2.14.4 Textiles

Gum is used widely in textile industry as sizing and finishing agent and for printing formulation for imparting design or decoration to fabrics (Davidson 1980).

2.14.5 Adhesive:

A 40% solution of powdered gum is safe, simple adhesive for miscellaneous paper products, postage stamps, envelopes, wall paper and labels. Gum glue is easy to prepare, light in color, odour less and very stable.

2.14.6 Miscellaneous uses

Gum Arabic in addition can be used in paints, inks, lithography, fixing car – wind shield, coating typing paper and preparation of good quality carbon – paper. The wood provides a high quality fire wood as is used for polesaticultural implements and well –lining. Fibers from roats are used for robes. Goats, camels and sheep eat the leaves and pods during the beginning of the dry season. Also the tree is important for fixing the moving sand. The gum belt is a natural buffer zone between desert proper in the north and the good agricultural tall grass savanna in the south. All this explain the high priority given by Sudan government for the production, improvement and development of gums.

2.15. Physicochemical properties.

The physicochemical properties of gums are important in specification, characterization and quality indication of gum, and also assist to differentiate between different gums. These properties vary with gums of different botanical sources, and even substantial different in gum from same species when collected from the plant at differences seasons of the year, different places and different ages of the same plant. The physical parameters used in gum analysis are the determination of moisture content, ash content specific rotation, Nitrogen content and protein content. Some Sudanese physicochemical properties of gums and analytical data are shown in Table (2.3, 2.4)

2.15.1Moisture content

Moisture content gives indication about the hardness of the gum and microbial load. It is determined by measuring the weight lost after evaporation of water (Person, 1970).

2.15.2. Ash content.

Ash content gives indication about the inorganic residues found in form of elements after removal of organic matters;it is generally affected by the type of the soil (Karamalla, 1998).

Table (2.3) Chemical analysis of African species gum (Younes, 2009)

Species	Ash%	N%	$[\alpha]_D^T$	H	MwX10^6	A.E.W	Uronic acid	References
A. ehrenbergiana	3.0	0.09	-0.7	07.00	0.27	1060	17.00	Anderson *et al.*,(1984)
A	1.30	0.23	+91	13.00	Nd	521	34.00	Anderson *et al.*(1984)
A .haroo	0.56	0.13	+54	Nd	1.46	nd	12.00	Anderson *et al.*,(1984)
A .kirbii	1.40	0.09	+54	08.00	0.21	1817	09.70	Anderson &Faquhan(1979)
A .nilottica	2.48	0.02	+108	09.50	2.20	1890	09.00	Anderson (11976)
A .nubica	1.54	0.02	+98	09.80	0.87	3030	07.00	Anderson *(1976)*
A .rubusta	ND	2.80	+36	Nd	0.72	1660	09.00	Chrmus & Stephen(1984)
A .sieberana	1.50	0.19	+103	12.00	0.14	1230	04.00	Anderson *et al.(1973)*
A .acatechii	0.28	Nill	-30	Nd	0.40	nd	03.30	Aganwwal & Soni(1988)
A .erubescens	3.90	1.08	-13	08.00	200	874	20.10	Anderson &Farquhan(1979)
A .fleckii	4.00	0.58	-32	13.00	415	918	19.20	Anderson &Farquhan(1979)
A .laeta	ND	0.56	-42	20.70	725	1250	14.00	Anderson *(1976,1977)*
A .mellifera	2.90	1.45	-56	23.50	410	843	20.90	Anderson &Farquhan(1979)*)*
A . polyacantha	ND	0.37	-12	15.80	Nd	2020	09.00	Anderson(1986)

Table (2.4) Analytical data of the gum exudates from different species of the Sudan.(Karamalla,1999)

Species	Moisture %	Ash%	N%	Protein %	pH	Titrable acidity	Relative Viscosity	Sp.Rot (degree)	Arabinose %	Rhamnose %	Methoxyl %
A . Sieberana var.sieberana	5.30	1.90	0.35	02.19	3.95	5.82	1.36	+74.16	41	03.0	-
A .sieberana var vermesenii	4.90	2.10	0.35	02.19	3.88	6.00	1.47	+77.16	48	05.0	-
A . nubica	4.60	0.30	0.35	02.19	3.50	10.20	0.50	+64.16	48	04.3	0.15
A .tortilis subsp. raddiana	4.40	1.80	1.84	11.50	3.60	8.50	0.77	+71.33	43	07.0	-
A .tortilis subsp . spirocarpa	6.40	2.03	1.40	07.50	3.85	6.50	0.76	+68.66	41	08.0	-
A . tortilis subsp. Tortilis	6.10	1.90	1.20	08.75	4.15	4.80	0.80	+69.00	58	05.0	0.57
A .drepandolobium	6.10	0.01	0.87	05.44	4.05	5.10	1.01	+75.83	49	02.0	0.40
A .grrardii	5.90	3.10	2.31	14.44	4.40	3.80	2.75	+48.50	37	09.0	-
A .ehrenbergiana	7.90	2.60	0.22	01.37	3.45	11.0	0.37	+5.66	39	08.0	-
A .nilotica subsp. nilotica	6.10	0.03	0.06	00.37	4.10	5.00	0.69	+97.66	42	01.8	1.14
A .nilotica subsp. tomentosa	5.80	0.04	0.10	0.62	4.48	4.15	0.90	+80.16	4	01.9	0.88
A .niloticasubsp .astringen	5.60	0.06	0.06	00.37	3.75	7.00	0.68	+75.16	39	01.0	-
A .laeta	3.20	0.51	0.51	03.19	3.70	7.70	1.12	-37.50	23	12.0	0.33
A . polyacantha	6.50	0.34	0.34	02.12	4.25	4.50	0.66	-19.10	31	9.0	-
A .seyal var.seyal	7.20	0.10	0.10	00.63	4.35	4.18	1.28	+50.50	52	04.0	1.02
A .seyal var. seyal	8.00	0.14	0.14	00.87	3.80	6.90	1.77	+42.66	49	07.0	0.90
A .senegal	7.40	0.33	0.33	01.87	4.66	3.60	1.40	-31.30	21	14.0	0.36

2.15.3. Viscosity.

Viscosity can be defined as the resistance of liquids to flow through capillary tube. It can be presented in many terms there are many different types of viscosities namely relative viscosity, specific viscosity, reduced viscosity, inherent viscosity, and intrinsic viscosity. Also it can be presented as kinetic or dynamic viscosity. Viscosity was considered as one of the most important analytical and commercial parameter, since it is a factor that includes the size and the shape of the macromolecules (Anderson *et al*; 1969).

2.15.4. Nitrogen content.

Protein as an integral of gum molecule was established by Akiyama *et al*. (1984).they indicated that the amino acid composition of gums is rich in hydroxyproline and serine. Dickinson (1991) studied the emulsifying behavior of gums and conducted that there was strong correlation between the proportion of protein in the gum and its emulsifying stability. So it is important to determine the contents of the nitrogen and protein in the gum.

2.15.5 Specific optical rotation

Many substances possess the inherent property to rotate the plane of, incident, polarized light; this property is called optical activity. The optical rotation is the angle through which the plane of polarized light is rotated when it passes through solution. Substances are described as dextrorotatory or levorotatory according to whether the plane of polarization is rotated clockwise or anticlockwise, respectively, as determined by viewing towards the light source .Dextrorotation is designated (+) and levorotation is designated(-).Specific rotation is considered as the most important criterion of purity and identity of Albizia amara gums (Mhinzi 2002)

2.15.6 Molecular weight of Gum

For determination of complete molecular weight, several steps have to be carried out. These range from the methods used in 1940and 1950, through the modern instrumental technique. It should be emphasized that these modern technique have not entirely replaced the classical methods, but in most cases, combination of these methods is necessary in the elucidation of macromolecular structure. The most successful general method available for the detailed structural studies of such complex polymer is to break it down into small workable fragments by hydrolysis to its monosaccharide or oligosaccharide constituents, then the hydrolysates are analysed by using the

traditional method for qualitative analysis or used modern technique like gas liquid chromatography and high performance liquid chromatography. Spectroscopic methods such as infra-red (IR), nuclear magnetic resonance (NMR) and mass spectroscopy (MS) were also used in structural identification of gum molecular weight.

2.15.7 Equivalent weight and Uronic acid anhydride.

Uronic acids are widely distributed in animal and plant tissues. They constitute a major component of many natural polysaccharides. Many methods have been used for the determination of glucuronic acid, these were: -

1. Modified uronic acid-carbazole reaction as proposed by Biiter and Muir.
2. Colormetric methods.
3. Acid-alkaline-titration method.

2.15.8 pH value.

The hydrogen ion concentration plays great important role in the chemistry and industry of the gums. The change in the concentration of hydrogen ions may determine the solubility of gum and the precipitation of protein. Crude gums are slightly acidic because of the presence of few free carboxyl groups of its constituent acidic residues, D-glucuronic acid and its 4-O-methy1 derivatives.

2.15.9 Sugar composition

Monosaccharide composition of plant gums are determined by acid hydrolysis of the gum, complete hydrolysis yields composite sugar constituents. Namely D- glactose, L- arabinose, L-rhmanose, and D- glucuronic acid.

2.15.10 Cationic composition

Cationic composition of gum samples analysis is not common but since gums are used as food additives is very important, the amount of heavy metals like (Pb) has to be minimal, and this is set as less than 2 ppm (FAO, 1999).

Table (2.5) Cationic composition of some gum samples (ppm)

Species	Mg	Ca	K	Na	Zn	Cu	Fe	Mn	Pb	Al	Cr	Ni	references
Senegal	24000	20600	1600	8400	9.0	32	54	3	0	111	39	3	Anderson *etal.,*1984[a]
Senegal	39000	316000	221000	10200	40	66	110	57	11	311	34	12	Anderson et al1989[b]
Senegal	38000	256000	237000	940	24	52	128	106	6.0	190	47	10	Anderson et al.,1990[f]
Senegal	1345-1987	5387-6314	6664-7735	3.9-12	0.2-0.4	1.1-1.5	2.5-6.9	2.4-8.8	0.84	4.1-11	0.27-0.34	0.22	Buffo et al .,2001[c]
Senegal	1009	6797	8057.9	792.4	-	23.96	4353	-	-	-	-	-	Omer(2006)[f]
Senegal	2159.704	7092.2	9459.459	67.1296	20.5125	-	37.0370	-	7.5757	-	-	-	Abdelrahman[f]
Senegal	267	6490	261	266	-	-	-	-	-	-	-	-	Younes(2009)[f]
Seyal	11.7	11200	7900	5.49	620	130	-	750	-	-	-	-	Siddig(2003)[d]
Seyal	27	7000	101100	9.67	13	51	190	200	-	-	-	-	Siddig(2003)[e]
Seyal	761	9824	2683	505.5	-	18.82	4339	-	-	-	-	-	Omer(2006)[f]
Seyal	1229.0424	9417.20	2802.803	111.054	7.8632	-	43.9815	-	-	-	-	-	Abdelrahman(2008)[f]
Seyal	419	7370	380	195	-	-	-	-	-	-	-	-	Younes(2009)[f]

A,b,d,e cited in Younces (2009) .c cited in Abdelrahman(2008). F cited in Amira 2011

Table (2.6) some physicochemical properties of *Albizia* gums (Gaspar S.Mhinzi2002)

parameter	*Albizia amara*	*Albizia harveyi*	*Albizia petersiana*
Moisture (%w/w)	16.0	15.8	14.9
Insoluble matter(%w/w)	1.20	0.22	1.68
CWIC(%w/w)	16.1	20.8	7.7
HWIG(%w/w)	14.0	17.6	7.4
Ash(%w/w)	5.5	4.9	5.1
Absorbance	0.10	0.12	0.16
Tannin(%w/w)	0.42	1.19	0.26
methoxyl(%w/w)	0.62	0.58	0.37
Acetyl(%w/w)	3.13	2.73	2.91
Sp.Rot (degree)	-11.0	-13.2	-27.2
nitrogen(%w/w)	0.51	0.46	1.09
Ph(15g/1aq.soln	4.9	4.8	4.5
% salt	93.8	94.9	83.6
AEW	1152	610	1171

CWIG, cold water- insoluble gel: HWIG, hot water insoluble gel: AEW, acid equivalent weigh

Table (2.7) Cationic composition of some *Albizia* gums (Gaspar S. Mhinzi 2002)

Element	*Albizia amara*	*Albizia harveyi*	*Albizia petersiana*
(%w/w)			
Ca	1.30	1.09	0.542
Mg	0.407	0.528	0.353
K	1.40	0.891	1.23
Na	0.029	0.018	0.006
(ppm)			
Fe	59.4	28.5	82.7
Zn	37.9	12.7	39.4
Pb	21.0	6.3	5.2
Cu	5.43	6.15	14.5
Al	17.9	7.4	13.0
Mn	167	126	97.1
Cr	7.36	0.71	0.23
Co	2.4	2.2	1.79

2.16 Emulsion Stability

Emulsion form basis of a wide variety of natural and manufactured material used in the Food, Pharmaceutical and Cosmetic industries (McClements, 2005).Existing and new ingredients are regularly incorporated into food system to improve their rheological, physicochemical and nutritional properties .At present, gums are one of the most, widely, used biopolymers in food and beverages (Randall *et al*.,1988). Its arabino galacto protein (AGP) component is responsible for its unequalled emulsifying properties, including the ability to form stable emulsion over a wide pH range and in the presence of electrolytes(Buffo *et al*.,2001).An emulsion is a dispersed system that consists of two immiscible liquids (usually oil and water), with one of the liquids dispersed as small droplets in the other called continuous phase (McCments, 1999).The emulsion are thermodynamic ally unstable systems and have a tendency to break down over time (Dickinson, 1992, Larsson ,1997, McClements, 1999).the breakdown of an emulsion may manifest itself through different physicochemical mechanisms such as gravitational separation, coalescence, flocculation, Ostwald ripening and phase inversion(McClements, 200). In general, emulsifiers are needed for stabilizing emulsion because they decrease the interfacial tension between the oil and water phase and form a protective coaling around the droplets which prevents them from coalescing with each other Dicknison (1988) distinguished between emulsifier and stabilizer in food

system. Emulsifier is defined as a single chemical or mixture of components having the capacity for promotion emulsion formation and short term stabilization by interfacial action while stabilizer is defined as a single chemical or mixture of components which can offer long term stability emulsion, possibly by mechanism involving adsorption but not necessarily so. Certain polysaccharides such as gum Arabic (Silber, 1975),Xanthan gum (prud, 1983) and Tragancanth gum (Dea, 1986) have been noted to display specific surface activities and stabilize dispersed particles of oil droplets in aqueous system. In line with this concept, the present study is designed to compare effects of factors, such as type of oil, stirring time and concentration on stability of emulsion prepared from *Albizia amara* gum samples.

2.17 Antioxidant properties of activity *Albizia amara* gums

Antioxidant compounds in food play an important role as health protecting factor. Scientific evidence suggests that antioxidants reduce the risk for chronic diseases including cancer and heart disease. Primary sources of naturally occurring antioxidants are whole grains, fruits and vegetables. Plant sourced food antioxidants like vitamin C, vitamin E, carotenes, phenolic acids, phytate and phytoestrogens have been recognized as having the potential to reduce disease risk. Most of the antioxidant compounds in a typical diet are derived from plant sources and belong to various classes of compounds with a wide variety of physical and chemical properties. Some compounds, such as gallates

have strong antioxidant activity, while others, such as the mono-phenols are weak antioxidants. The main characteristic of an antioxidant is its ability to trap free radicals. Highly reactive free radicals and oxygen species are present in biological systems from a wide variety of sources. These free radicals may oxidize nucleic acids, proteins, lipids or DNA and can initiate degenerative disease. Antioxidant compounds like phenolic acids, polyphenols and flavonoids scavenge free radicals such as peroxide, hydroperoxide or lipid peroxyl and thus inhibit the oxidative mechanisms that lead to degenerative diseases. There are a number of clinical studies suggesting that the antioxidants in fruits, vegetables, tea and red wine are the main factors for the observed efficacy of these foods in reducing the incidence of chronic diseases including heart disease and some cancers.

2.17.1 Reactive oxygen species

Reactive oxygen species (ROS) is a term which encompasses all highly reactive, oxygen-containing molecules, including free radicals. Types of ROS include the hydroxyl radical, the superoxide anion radical, hydrogen peroxide, singlet oxygen, nitric oxide radical, hypochlorite radical, and various lipid peroxides. All are capable of reacting with membrane lipids, nucleic acids, proteins and enzymes, and other small molecules, resulting in cellular damage. ROS are generated by a number of pathways. Most of the oxidants produced by cells occur as:

• A consequence of normal aerobic metabolism: approximately 90% of the oxygen utilized by the cell is consumed by the mitochondrial electron transport system.

• Oxidative burst from phagocytes (white blood cells) as part of the mechanism by which bacteria and viruses are killed, and by which foreign proteins (antigens) are denatured.

• Xenobiotic metabolism, i.e., detoxification of toxic substances.

Consequently, things like vigorous exercise, which accelerates cellular metabolism; chronic inflammation, infections, and other illnesses; exposure to allergens and the presence of "leaky gut" syndrome; and exposure to drugs or toxins such as cigarette smoke, pollution, pesticides, and insecticides may all contribute to an increase in the body's oxidant load.

2.17.2 Antioxidant protection

Antioxidants are nutrients in food that protect your cells from damage from free radicals.

• Free radicals are unstable molecules that can damage cells. Your body creates them when you digest food.

• This cell damage may increase the risk of cancer on set, heart disease, cataracts, diabetes, or infections. Free radicals may also affect brain function.

2.17.3 Tips for getting more antioxidants

• Eat a rainbow of fruits and vegetables. The colors of fruits and vegetables are clues about the types of nutrients they provide. To get a variety of nutrients, eat a variety of colors Table (2.8).

• Be adventurous in the produce section:

Choose a colorful fruit or vegetable you have never tried before. Encourage your family to pick a new fruit or vegetable each time you shop.

• Plan at least two dinners per week with beans as the main source of protein. Good choices are rice and beans or hearty bean soups.

• Experiment with fresh herbs and spices.

• Choose whole grain products, such as whole wheat bread and brown rice.

• Add nuts to salads, soups, and cereal.

• Snack on fresh vegetables with bean dip.

• Eat salsa as a snack, with your scrambled eggs, on a baked potato, or with vegetables.

2.17.4 Types of antioxidants

Many nutrients are antioxidants, Examples include:

Vitamin A, Vitamin C, Vitamin E, Anthocyanins, Beta carotene, Catechins , Ellagic acid, Lutein, Lycopene, Resveratrol and Selenium. Foods probably contain other antioxidants that are still undiscovered. Eating a wide variety of foods will help you get the full benefit of these antioxidants.

Table 2.8 Sources of foods antioxidants.

Food	Antioxidant Nutrients
Acorn squash, pumpkin, winter squash	Beta carotene
Apples	Catechins
Apricots, cantaloupe, peaches	Beta carotene
Beans	Catechins, vitamin E
Beets	Anthocyanins
Bell peppers	Beta carotene, vitamin C
Berries	Anthocyanins, catechins, ellagic acid (in raspberries and strawberries), resveratrol (in blueberries), vitamin C
Broccoli, greens, spinach	Beta carotene, lutein, vitamin C
Brown rice	Selenium
Carrots	Beta carotene
Chicken	Selenium
Citrus fruits	Vitamin C
Corn	Lutein
Egg	Lutein (in yolks); selenium, vitamin A
Eggplant	Anthocyanins
Garlic and onions	Selenium
Grapefruit, pink	Lycopene, vitamin C
Grapes, red wine	Anthocyanins (in red and purple grapes), resveratrol
Mango and papaya	Beta carotene, vitamin C
Milk	Vitamin A
Nuts, nut butters, oils, seeds	Vitamin E
Oatmeal	Selenium
Peanuts	Resveratrol
Prunes	Anthocyanins
Salmon, tuna, seafood	Selenium
Sweet potatoes	Beta carotene, vitamin C
Tea, black or green	Catechins
Tomatoes (canned)	Lycopene, vitamin C
Watermelon	Lycopene, vitamin C
Wheat germ, whole grains	Selenium, vitamin E

2.18.Thermodynamic properties of *Albizia amara* Gum Solution

2.18. 1 Introductions

Chemical and physical processes are almost invariably accompanied by; energy change .chemistry can be viewed as being based on the interrelated physical factors of energetic, structure, and dynamics. In some ways, energetic behavior

of molecules determines their structure and reactivity. Thermodynamics has an immense predictive power and the thermodynamic laws can be used to predict the direction in which a process would proceed .to understand the behavior of gum molecule in solution it is necessary to measure and calculate some thermodynamic parameters and functions. Thermodynamic of polymer solution can be applicable to gum solutions since gum molecules are classified as biopolymer molecules. Solutions are characterized by thermodynamic parameters like the volume, internal energy, Gibbs free energy, entropy, and enthalpy. However, one usually makes use of the differences of these quantities in two specified states of the system .in the case of solution processes it is customary to refer to the difference between the thermodynamic functions of the solution and the same function of the components before dissolving ,the properties of real solution are non additive for example:

$$v_{sol} \neq \sum v_{comp}$$

$$G_{sol} \neq \sum G_{comp}$$

Hence ,the volume ,enthalpy ,entropy ,e t c. of components in solution differ from their values before dissolving .this made it necessary to introduce the concept of partial molar (specific) function to characterize the thermodynamic behavior of the components in a solution (Tager,1978)

2.18.2 Weight fraction (w)

The weight fraction of a component is the ratio of its weight to the sum of weight of all the components.

$$\omega_1 = g_1 / g_1 + g_2 \quad \text{……. (2.18.2.1)}$$

$$\omega_2 = g_2 / g_1 + g_2 \quad \text{…… (2.18.2.2)}$$

Where g1 and g_2 are the weight of component 1 and 2 respectively.

2.18.3 The molar fraction (N)

It is the most useful concentration variable for theoretical understanding of solution of like –size molecules .the mole fraction of a component (N_i) of a binary solution is calculated from the following equation.

$$N_1 = n_1 / n_1 + n_2 \quad \text{…….. (2.18.3.1)}$$

$$N_2 = n_2 / n_1 + n_2 \quad \text{…… (2.18.3.2)}$$

Where n1 and n2 number of moles of component involved

2.18.4 Volume fraction (Φ)

The volume fraction of a component (ϕ_1) is the ratio of its partial molar (specific) volume to the total volume of the solution .for the binary system for instance ϕ_1 is given as (Tager, 1978).

$$\phi_1 = \overline{V}_1 / \overline{V}_1 + \overline{V}_2 \quad \text{…… (2.18.4.1)}$$

$$\phi_2 = \overline{V}_2 / \overline{V}_1 + \overline{V}_2 \quad \text{…….. (2.18.4.2)}$$

Where: $\overline{V}_1$ is partial molar (specific) volume of the solvent

$\overline{V}_2$ is partial molar (specific) volume of the solute.

2.18.5 Partial molar (specific volume) ($\overline{V}$)

In general the partial molar volume of a substance A in a mixture is the change in volume per mole added to a large volume of the mixture. If the molecular masses of the components are not known exactly, so that their mole fraction cannot be calculated, it is more convenient to use specific partial function, i.e function referred to one gram rather than to one mole of the component.

A partial specific function ($Z_{i\,sp}$) equals the partial molar function ($Z_{i\,mol}$)

Divided by the molecular mass (M_i) of the component.

$$Z_{i\,sp} = {}^{Z_{imol}}\!/_{M_i} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2.18.5.1)$$

To discuss the determination of partial molar volume of liquid solution, it is convenient to write the volume (V_m) of a binary solution as a function of the partial molar volumes of the two components and their mole fraction ($N_1.N_2$).

$V_m = N_1\overline{V}_1 + N_2\overline{V}_2$ …… (2.18.5.2)

The molar volume of a solution can be calculated from its density and composition (Karolina ,2005) .for a binary solution the molar volume at constant temperature and pressure can calculated by graphical method there are two graphical methods for calculating partial molar (specific) volume (Tager,1978)

(1) Tangent methods

The volume of the solution (V) is plotted against the number of moles (n) or grams (g) of one of its components. Evidently, the derivative ∂ V/∂ n or ∂ V/∂ g

determined at any point of the curve, equal the partial molar (specific) volume of the component in a solution of the corresponding concentration (Tager1978).

(II) Intercept methods

The intercept method, constant in plotting the value of volume (V) or its change (Δv) referred to one mole of solution V_{tot} / (n_1+n_2).if the volume referred to one gram of solution (V/g_1+g_2) are plotting along the ordinate is against composition in weight fraction (w) , the tangent intercepts on the ordinate will be numerically equal to the partial specific function: Tager(1978)) and Paijk, et al. (1990) studied the density of aqueous solution of some monosacharides (D-pentoses and D-hexoses). The mean molar volumes of the solution were found to be linearly dependent on the mole fraction of the solute. Thus, the partial molar volume of solvent and solute respectively, are concentration-independent; i.e, the partial molar volume of the solvent equals the molar volume of the pure solvent, and the partial molar volume of the solute is equal to its value at infinite dilution .The graphical methods described by Lewis and Randall (1923) are used in the determination of the apparent molar volume ϕ_v which is defined by the relation.

$$\phi_v = \left(v - n_1 v_0 \Big/ n_2 \right) \text{..... (T, P constant)}$$

2.18.6 Chemical potential (μ)

One of the most function characteristics in behavior of each component in a solution is the chemical potential of the component. The chemical potential equals the change in internal energy of a solution on addition of an infinitely

small number of moles of the component, referred to that amount of substance at constant volume .entropy, and quantity of each of the other component.

$$\mu_1 = \left(\partial\mu / \partial\mu_i\right)_{v,s,nj(j\pm i)} \quad \text{..... (2.18.6.1)}$$

$$\Delta G = \Delta\mu \quad \text{..... (2.18.6.2)}$$

Since

$$\Delta G = \Delta H - T\Delta S \quad \text{..... (2.18.6.3)}$$

$$\Delta\mu = \Delta H - T\Delta S \quad \text{..... (2.18.6.4)}$$

The change in chemical potential of solvent with environmental pressure at constant temperature is given by equation.

$$\left(\partial\mu / \partial p\right)_T = \overline{V} \quad \text{..... (2.18.6.5)}$$

Or

$$\partial\mu_i = \overline{V}\, dp \quad \text{..... (2.18.6.6)}$$

Hence

$$\int_{\mu_1}^{\mu_{10}} d\mu_1 = \int_{p^0}^{p} \overline{V} dp \quad \text{..... (2.18.6.7)}$$

Assuming v to be constant, we obtain after integration.

$$\mu_1^{\,0} - \mu_1 = V(p - p^0) = \overline{V}_1\, \pi \quad \text{.....(2.18.6.8)}$$

$$\mu_1^{\,0} - \mu_1 = \overline{V}\ \pi \quad \text{..... (2.18.9)}$$

Where π = osmotic pressure.

$\overline{V}$ = partial molar (specific) volume of solvent.

Hence

$$\mu_1 - \mu_1^{o} = \Delta\mu_1 \ldots\ldots\ldots\ldots\ldots\ldots \quad (2.18.6.10)$$

$$\mu_1 - \mu_1^{o} = -\overline{V}\,\pi \ldots\ldots\ldots\ldots\ldots\ldots \quad (2.18.6.11)$$

3.18.7 Ideal and nonideal solutions

Ideal solution are those which form with a zero heat effect ($\Delta H=0$) and ideal entropy of mixing equal –Rln N. Consequently, in accordance with equation (2.18.6.4) the change in chemical potential of the component in an ideal solution equals.

$$\Delta\mu_i = -T\,\Delta S_i = RT\ln N_i \ldots\ldots\ldots\ldots\ldots\ldots \quad (2.18.7.1)$$

i.e. depend only on the mole fraction of the component in the solution .In this case of a real solution .

$$\Delta\mu_i = \Delta G = RT\ln \left(p_1 / p_{1^0} \right) \ldots\ldots\ldots\ldots\ldots\ldots (2.18.7.2)$$

Where Pi and P_i^{o} are the partial vapour pressres of the its component above the solution and above the component respectively.

2.18.8 Osmotic pressure (π)

Osmotic is the phenomenon of penetration of a solvent into a solution through a semi permeable membrance. The tendency of solvent molecules to pass spontaneously into a solution, due to quantity of chemical potential of pure solvent and a solution estimated quantitatively by osmotic pressure, which has the dimension of pressure (atm).The osmotic pressure of a solution is equal to the additional pressure which must be applied to the solution to make the chemical

potential of the component in solution equals to the chemical potential of the pure solvent

$$\pi = p - p0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2.18.8.1)}$$

A comparison of equation (2.18.7.1) and equation (2.18.8.1) show that the osmotic pressure of an ideal solution can be given by the relation

$$\pi = \left(RT / V_{1^0} \right) \ln N_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2.18.8.2)}$$

Or

$$\pi = -(RT/V_1^0) \ln (1-N_2)\ldots\ldots\ldots\ldots\ldots..$$

Expanding ln $(1-N_2)$ in a series, and using the first term of this series for high dilution, we obtain

$$\ln N_1 = \ln(1 - N_2) = -N_2 - N_2^2/2 - \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2.18.8.3)}$$

$$\pi = \left(RT / V_1^0 \right) N_2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2.18.8.4)}$$

The mole fraction of a component is

$$N_2 = n_1 / n_2 + n_2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2.18.8.5)}$$

Where n_1 and n_2 are the number of moles of the components. if $n_{1>>}n_2$ then $N_2 = n_2/n_1$ .substituting this expression into equation (2.18.8.4)

We get.

$$\pi = \left(RT / V \right) n_2 = c_2 RT \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2.18.8.6)}$$

Where V= volume of solution, equal to $n_1 V_1^0$

$C=n_2/V$= concentration of a solute in units of mole/litre.

Equation (2.18.8.6) that was first derived empirically by va't Hoff, Known as the Van'Hoff equation, $\mu = cRT$, does not apply to polymer solution , even though they are very dilute. The concentration dependence of osmotic pressure is expressed by more complex equation which results if the concentration c is replaced by power series (Flory, 1953)

$$\pi = RT\left(A_1c + A_2c^2 + A_3c^3\right) \text{ ..... (2.18.8.7)}$$

Or

$$\pi/C = RT\left(A_1 + A_2c + A_3c^2 + ...\right) \text{.....(2.18.8.8)}$$

Where c = concentration of a polymer in a solution (g/ml)

A_1, A_2, A_3, are first, second and third virial coefficients.

The first virial coefficient A_1 is related directly to the molecular mass of a polymer by the relation $A_1=1/Mn$ (Tager, 1978). Hence, equation (2.18.8.8) may be written in the following form.

$$\pi/c = RT\left(1/M_n + A_2c + A_3C^2 + ...\right) \text{.....(2.18.8.9)}$$

Equation (2.18.8.9) can be written in the following form (Billmeyer, 1971. Krigbaum and Flory, 1953).

$$\pi/c = RT/M_n\left(1 + \Gamma^2c + g\Gamma^2c^2 + ...\right) \text{ ..... (2.18.8.10)}$$

Where $\Gamma = A_2/A_1$ and g is a slowly varying function of the polymer – solvent interaction with values near zero for poor solvents and near 0.25 for good solvents

(krigbaum, 1952. Stockmayer, 1952). 1n most cases, the term c2 may be neglected; when dependence on c2 is significant, it may be convenient to take g = 0.25 and equation (2.18.8.10) becomes.

$$\pi/c = RT/M_n \left(1 + \Gamma/2 c\right)^2 \quad \ldots\ldots\ldots\ldots\ldots \text{(2.18.8.11)}$$

In terms of the polymer –solvent interaction constant $x_1$of the Flory –Huggins theory, the osmotic pressure is given by.

$$\pi/c = \left(RT/M_n\right) + \left(p_1/M_1 p_2^2\right)\left(1/2 - \chi_1\right)C + \ldots\ldots\ldots\ldots \text{(2.18.8.12)}$$

Where subscript 1 indicates the solvent, and 2 the gum.

According to equation (2.18.8.10) and (2.8.8.13) ,it is usual to plot π/c vs .c .In general a straight line results whose intercept at c= 0 is A_1 = RT/Mn, and whose slope is the second virial coefficient (A_2) that allows evaluation of polymer – solvent interaction x_1. If the solvent is good enough, or the concentration is high enough then the c_2 term is significant, but the points may deviate from a straight line. In such cases it is useful to plot $(\pi/c)^{1/2}$ versus c as suggested by equation (2.18.8.11), which can be written as follows:

$$\left(\pi/C\right)^{\frac{1}{2}} = \left(RT/M_n\right)^{\frac{1}{2}}\left(1 + \Gamma/2 c\right) \; (\pi/c)^{1/2} = \ldots\ldots\ldots\ldots \text{(2.18.8.13)}$$

Since

$$\Gamma = A_2/A_1 \; and A_1 = 1/M_N$$

We can write

$$\left(\pi/c\right)^{\frac{1}{2}} = \left(RT/M_n\right)^{\frac{1}{2}} + \left(RT/M_n\right)^{\frac{1}{2}} A_2 M_n/2\, c \quad \text{.....(2.18.8.15)}$$

$$\text{The intercept} = \left(RT/M_n\right)^{\frac{1}{2}} \text{..... (2.18.8.16)}$$

$$\text{The slope} = \left(RT/M_n\right)^{\frac{1}{2}} A_2 M_n/2 \text{..... (2.18.8.17)}$$

If the second virial coe fficients equal zero, the solvent is called ideal solvent.

The better solvent has the higher value of A2 (Figure 2.4).

For an ideal solvent, $A_2 = 0$

For good solvent, $A_2 > 0$

For poor solvent $A_2 < 0$

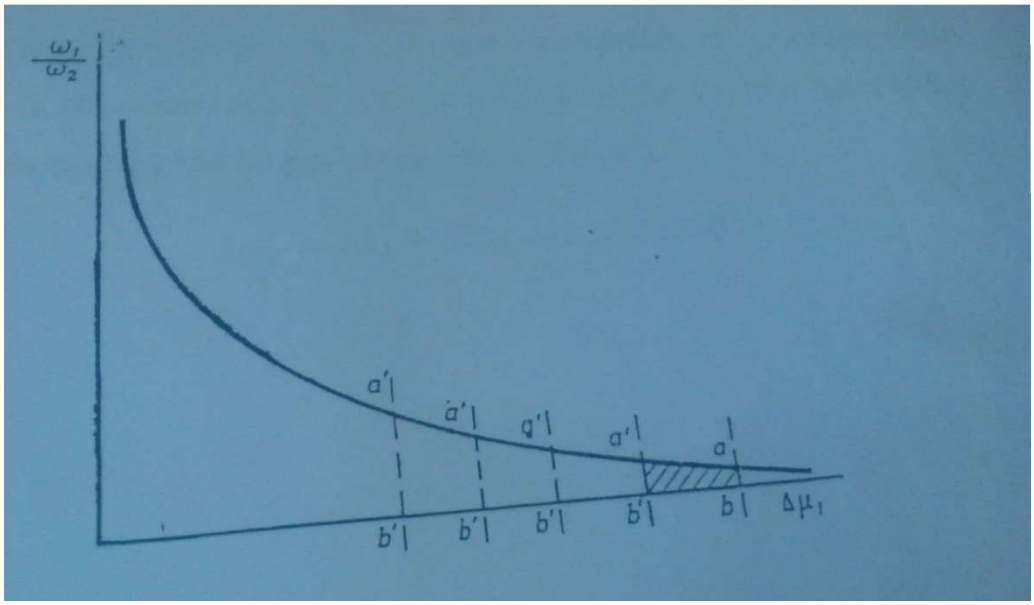


Figure (2.4) Dependence of π/C_2 on concentration of polymer solution in various solvents.

2.18.9 Polymers – solvent interaction parameter

Parameter χ_1 is the measure of thermodynamic affinity of a solvent for the polymer, or measure of quality of a solvent. The smaller χ_1, the better is the solvent thermodynamic ally. For very poor solvent. χ_1 may be higher than unity ,and for very good once , χ_1 may be negative .

The parameter $\chi_1$can be determine from osmotic pressure by using the following equation (Tager, 1978)

$$\pi = -\left(RT/V_1\right)\ln\phi_1 - \left(RT/V_1\right)\left(1 - V_1/V_2\right)\phi_2 - \left(RT/V_1\right)\chi\phi_2^2 \ldots (2.18.9.1)$$

After transformation and replacing volume fraction with concentration expressed in g cm^3 ($c = \phi_2 d_2$) the flowing equation results.

$$\pi/C = \left(RTd_1c^2/3M_1d_2^3\right) = RT/M_2 + \left(RTd_1/M_1d_2^2\right)\left(1/2 - \chi_1\right)c \ldots\ldots (2.18.9.2)$$

Where d_1 and d_2 = densities of a solvent and a polymer and M_1 and M_2 are their molecular masses respectively.

At low concentration the second term on the left –hand side of the equation is small and may be neglected. The graphical representation of the equation is straight line and the slope of this line is ($RTd_1/M1d_2^2$) (1/2- χ_1) Hence it is possible to calculate the second viral coefficient:

$$A_2 = \left(d_1/M_1d_2^2\right)\left(1/2 - \chi_1\right) \ldots\ldots\ldots\ldots (2.18.9.3)$$

χ_1 iS a dimensionless parameter equals to the ratio of the energy of interaction of the polymer with the solvent molecules to the kinetic energy Rt .which should not depend on the concentration of a solution .

For an ideal solvent A_2 =0: χ_1= ½

For good solvent A_2 >0: χ_1< ½

For poor solvents A_2 < 0: χ_1> ½

2.18.10 Free energy of mixing of polymer with a solvent

To calculate the free energy of mixing ΔG^m .it is necessary to know the chemical potential of a polymer or, to be more exact, the quantity $\Delta\mu_2$.

Its value is calculated by using the Gibbs –Duhem equation for specific quantities (Tager, 1978).

$$\omega_2 d\Delta\mu_2 = - \omega_1 d\Delta\mu_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.18.10.1)$$

Where ω_1 and ω_2 are weight fraction of component 1 and 2.

Hence,

$$\Delta\mu_2 = -\int \left(\omega_1 / \omega_2 \right) d\left(\Delta\pi_1\right) + C \ldots\ldots\ldots\ldots\ldots\ldots (2.18.10.2)$$

To solve this equation, it is necessary to plot a graph of dependence of ω_1/ω_2 on $\Delta\mu_1$.(Figure 2.5)

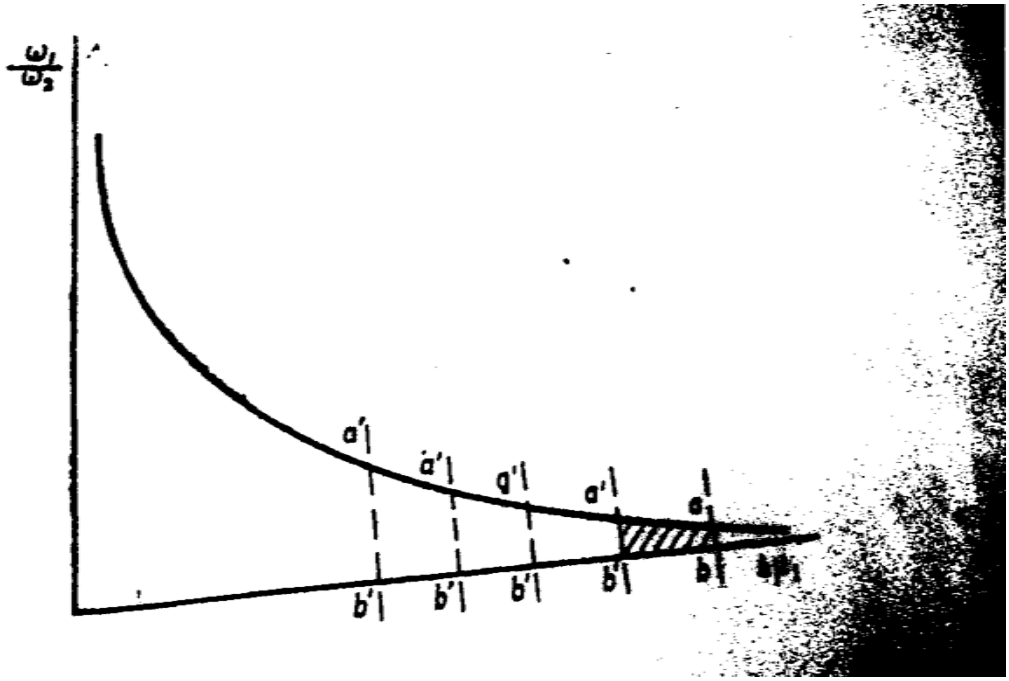


Figure (2.5) variation of ω_1/ω_2 with $\Delta\mu_2$

For $\omega_2 = 1$ ($\omega_1 = 0$) the ratio $\omega_1/\omega_2 = 0$ and $\Delta\mu_1 \rightarrow -\infty$.

For $\omega_1 = 1$($\omega_2 = 0$) the ratio $\omega_1/\omega_2 = \infty$ and $\Delta\mu_1 = 0$

Hence, the curve goes with both ends into infinity, and the integral may be determined within the limits ranging from - ∞ to certain value of $\Delta\mu_1$which corresponds to the concentration of a solution.

$$\Delta\mu_2 = \int_{-\infty}^{\Delta\mu_1} \left(\omega_1/\omega_2\right) d\left(\Delta\mu_1\right) \ldots\ldots (2.18.10.3)$$

Such an improper integral is replaced with a proper integral which is analogous to it. In this case, the finite value $\Delta\mu_1'$ which conforms to concentration ω_2' less than one is taken as the lower limit. Thus, the areas under the curve, that are bounded by ordinates corresponding to $\Delta\mu_1'$ at ω_2' and $\Delta\mu_1$ at different values of ω_2

calculated (Figure4.2). The calculated areas for $\Delta\mu_2^{/}$ are less than the true values obtained of $\Delta\mu_2$, a graph of dependence $\Delta\mu_2$ =f (ω_1) is plotted: in the region of concentration close to ω_2 = 1, it is rectilinear. On extrapolating the straight line to $\omega_2 \to 1$, we obtain segment A. However, at ω_2= 1, $\Delta\mu_2$ =0 it follows that the true values of $\Delta\mu_2$ differ from $\Delta\mu_2^{/}$ by the length of segment A (Figure 2.5)

$$\Delta\mu_2 = \Delta\mu_2^{'} + A \ldots\ldots\ldots\ldots \text{(2.18.10.4)}$$

This is an ordinary way of approximately calculating $\Delta\mu_2$. Knowing $\Delta\mu_1$and $\Delta\mu_2$ the average free energy of mixing per gram of a solution can be calculated.

$$\Delta G^M = \omega_1\Delta\mu_1 + \omega_2\Delta\mu_2 \ldots\ldots\ldots\ldots\ldots\ldots \text{(2.18.10.5)}$$

Good solvents are liquids whose mixing with polymer is accompanied with great changes in the chemical potentials of components and the free energy of the entire system, and with large values of osmotic pressure and positive values of the second virial coefficients.

Chapter Three

Materials and Methods

3.1 Materials

3.1.1 Sampling

Thirty five, representative, natural exudates sample of the crude gum were collected from south Darfur region over three harvests of seasons 2012, 2013 and 2014.

3.1.2 Purification of crude gum

The gum samples, used in this work, were relatively pure; however, impurities such as wood pieces and sand particles were carefully removed by hand. Then each sample was reduced to a fine powder using a mortar and pestle and kept in labeled self sealed polyethylene bags.

3.1.3 Physical properties of *Albizia amara* gum

3.1.3.1 Color

The color of the gum nodules was pale yellow to brown.

3.1.3.2 Shape

The shapes of the gum nodules, as exuded naturally, were irregular or tear shaped.

3.1.3.3 Solubility

Albizia Amara gum is highly soluble in water forming transparent solution, and classified as a soluble gum.

3.1.4 Apparatus

- Gel permeation chromatography- Multi – angle light Scattering

- High performance Liquid Chromatograph, model

-Atomic absorption spectrometer, Perkin -Elmer

- Refractometer, model

- Digital balance

- PH meter, model

- Oven, model

-Furnace, model

- Polarmeter, model

- Osmomat 050 , model

- Uv spectrophotometer, model

-Infra Red spectrophotometer, model

3.2 Methods

3.2.1 Determination of Moisture content

Accurately weighed 0.5 gram of each sample was weighed in a clean preheated and weighed dish. Then it was dried in an oven at 105 ^{o}C for 12 hours to a constant weight. Moisture content was then calculated as a percentage of the initial weight from the following relation;

Moisture content (%) = w_1-w_2/w_1 x100

W_1 = Original weight of sample (g).

W_2 = Weight of sample after drying (g).

3.2.2 Determination of Ash

Accurately weighed 3.0 grams of the dried sample were ignited in a muffle furnace at 550 ^{o}C for 12 hours and ash % was calculated from the following relation;

$$\text{Ash (\%)} = \frac{W_3 - W_1}{W_2 - W_1} \text{ X } 100$$

Where:

W_1 = Weight of the empty crucible.

W_2 = Weight of the crucible + the sample.

W_3 = Weight of the crucible + ash.

3.2.3 pH measurement

PH meter was calibrated using two different buffers one adjusted at pH 4 and other at pH 11. Then after calibration it was used for determination of the pH of the gum fractions, of 1g/100 ml aqueous solution (w/v) calculated on dry weight basis.

3.2.4 Determination of Specific optical rotation $[\alpha]_D^T$.

Accurately weighed quantities of gum samples (3.0 g were dissolved in 100 ml of distilled water to give a solution of 3% w/v and mixing on a roller mixer until the sample dissolved fully. The solutions were centrifuged for 20 min at 2500 rpm and the optical rotation was measured against the D-line of Na (589.3nm) using a Perkin-Elmer polarimeter (20 cm path length, 25 ^{0}C), using distilled water as a blank between each measurement. The specific rotation was calculated according to the relationship:

$$[\alpha]_D^T = \frac{\alpha \times 100}{l \times c}$$

Where:

α = Observed angle of rotation.

I = the length of sample holder in decimeters.

C = the gram of sample per 1 ml of solution

T = Temperature.

D = Length of sodium light 589.3nm.

3.2.5 Total glucouronic acid.

A glass column was packed with an Amberlite Resin IR ($120H^{+}$). HCl was passed through the column until the resin was thoroughly washed with the acid. Then this was followed by distilled water until the column was chloride free. 50 ml of 3.0 % gum solution was passed through the column, followed by the distilled water until a volume of 250 ml of the eluent and washing were collected. This was titrated against 0.1N NaOH. The apparent equivalent weight of the acid was calculated by:

$$\text{A.E.W.} = \frac{\text{Weight of sample}}{\text{Volume of titrate X molarities of alkali}} \text{ X } 1000$$

% of uronic acid anhydride is calculated by:

$$\text{U. A. A.} = \frac{194 \text{ X } 100}{\text{A.E.W}}$$

Where: A.E.W. Is the apparent equivalent weight.

194 = Molecular weight of uronic acid.

3.2.6 Intrinsic Viscosity

Measurement of dilute solution viscosity (resistance to flow) provide the simplest and most widely used technique for routinely determining molecular weight, it is not an absolute method , and each polymer system must be first calibrated with absolute molecular weight determination (usually light scattering) run on fractionated polymer samples . Viscosities (on successive dilutions) are measured by determining the flow time of a certain volume of solution through a capillary viscometer at constant temperature .The viscosity of a solution may have a complicated variation with composition due to possibility of hydrogen bonding among the solute and solvent molecules hydroxyl groups make high viscosities because of hydrogen bonding to these O-H groups. Viscosity can be expressed in several terms .

$$\eta_{rel} = \eta / \eta^0 = t / t^0 \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where η and η^0 refer to solution and solvent viscosity respectively, in poise units (dynes cm^{-2} sec or g $cm^{-1}sec^{-1}$) or Pascal seconds, t and t^0 the flow time of the solution and pure solvent through capillary viscometer respectively.

The specific viscosity η_{sp} is the relative viscosity minus one:

$\eta_{sp} = \eta_{rel} - 1$……..(2)

The division of η_{sp} by concentration of the solution (c) gives reduced viscosity (viscosity number) η_{red} .

$\eta_{red} = \eta_{sp} / c$……(3)

The inherent viscosity (logarithmic viscosity number) can be expressed in the equation.

$\eta_{inh} = \ln \eta_{rel} / c$……(4)

Intrinsic viscosity (limiting viscosity number) [η] is determined by extrapolating a plot of either reduced or inherent viscosity versus concentration to zero.

$[\eta] = \lim (\eta_{sp}/C)_c = 0 = (\eta_{inh})_c = 0$……..(5)

Mark and Houwink arrived at an empirical relationship between molecular weight and the intrinsic viscosity.(83)

$[\eta] = KM^a$ …… (6)

Where K and a are constants which depend on the nature of the polymer and solvent. the terms K and a represent the slope and intercept ,respectively ,of a plot of log [η] versus log molecular weight of a series of fractionated polymer samples whose molecular weight have been determined by absolute methods (i.e .light scattering)

3.2.7 Nitrogen content

Nitrogen content was determined using a semi – micro Kjeldahl method according to (AOAC, 1984). Hence protein was determined by multiplying Nitrogen content by the 6.25 as factor (Anderson *et al*., 1986).

- **Nitrogen content:**

The procedure used is a two stage; process in which the gum samples are digested in hot concentrated sulphuric acid, the ammonia released using sodium hydroxide is neutralized using standard acid.

i) Digestion:

Sample + H_2SO_4 conc. + (Mercuric oxide as catalyst) +heat → $(NH_4)_2SO_4$

$(NH_4)_2SO_4$ + NaOH —steam → $2NH_3 + Na_2SO_4 + 2H_2O$

ii) Neutralization:

$NH_3 + H_3BO_3 \rightarrow NH_4^+ + H_2BO_3^-$

The Borate anion equivalent to the ammonia produced is back titrated with standard Hydrochloric acid (0.02 M)

$H_2BO_3^- + HCl \rightarrow H_3BO_3 + Cl^-$

Accurately weighed samples of the dry gum 0.2g were transferred to the digestion tubes to which a catalyst tablet and 10 cm^3 of concentrated sulphuric

acid were added. The tube was placed in the digestion heating system which was previously set to 240 ^{o}C. Complete digestion was attained when the heated solution turned into clear yellowish – green coloration. The tubes were allowed to cool to room temperature. Blanks containing 10 cm^3 of sulphuric acid and catalyst were digested in the same way as the test samples. The blanks and the samples were analyzed by the addition of sodium hydroxide (40%) followed by steam distillation. A mmonia released was absorbed in a known volume of boric acid and the borate anion generated is back titrated with 0.02 M hydrochloric acid. The volume required to neutralize the borate anion is determined.

The nitrogen content of the samples is calculated as follows:

$$N\ (\%) = \frac{14.01 \times (0.02\ M) \times (\text{vol. of titrate blank})}{\text{Weight of the gum sample/ g}}$$

3.2.8 Refractive index

Refractive index of 3%*Albizia Amara gum* solution was determined at room temperature using Refractometer .

3.2.9 Determination of cationic composition.

3.2.9.1 Method

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 ^{o}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 minutes. Cool, filter into a 100 cm^3 volumetric flask, and dilute to volume with deionized water then the elements were determined using AAs.

3.2.10 Determination of Sugar composition

3.2.10.1 Sample preparation

The samples were hydrolysed to liberate the sugar residues .Sample (100mg) L was accurately weighed, including allowance for moisture content, added to 10cm^3 of 4% H_2SO_4 and incubated at 100^{o}C for 6 hours. Following this ,1g of $BaCO_3$ added to the solution and left overnight (minimum of 12 hours) to neutralize the solution .After $BaCO_3$ treatment ,universal indicator strips were used to ensure that the sample was neutral before proceeding to the next stage . The solution was then centrifuged at 2500rpm for 10 minutes to allow the barium sulphate (formed from neutralizing the H_2SO_4) to settle. The supernatant was removed and filtered through a 0.45 µm whatman nylon filter and then diluted 1:1with 70/30 Acetonitrile /buffer. This constituted the final solution of which 1ml was analyzed using HLPC in the central lab Khartoum University.

3.2.10.2 Method

The purpose of analyzing the sample by HPLC was to determine the relative concentration of each sugar residue present in the sample .namely rhamnose (Rha) ,arabinose (Ara) ,galactose (Gal) and glucuronic (GlcA).

Before analysis of the gum samples, calibration curves of these sugars were prepared .Stock concentration of 5 mg cm^3 for each sugar were made up by hydrating in 70/30 Acetonitrile /buffer for 2 hours .Dilutions of the stock solution achieved six different concentration for each sugar over a range of 2.5 -0.5 mg cm^3 .this allowed six levels for the calibration curve and an average of replicates for each level was used to ensure accuracy .This calibration allowed the determination of the unknown sugar content for the gum samples. The concentration of each sugar was calculated by peak height and expressed as % of the total sugar content.

3.2.11 Density of solid gum

The density and the specific volume of the gum give good idea about the distance between the moleculares .The densities of the gum cannot be affected by it. Gradient tube method also used to determine the density of the polymer (Tager, 1978).

3.2.12 Determination of the Number average molecular weight.

An important group of absolute methods allowing the determination of the molecular weight of macromolecules is based on the measurement of colligative properties. Here, the activity of the solvent is measured in a polymer solution via determination of the osmotic pressure π_{os}. The value of π_{os} required to determine the number-average molecular weight can be obtained using a membrane osmometer. Here, in a measuring cell having two chambers separated by a semi permeable membrane, one chamber contains the pure solvent and the second one the polymer solution in the same solvent (a membrane is called semi permeable if only the solvent can pass through but not the polymer molecules). Due to the lower activity (lower chemical potential) of the solvent in the polymer solution as compared to the pure solvent, solvent molecules migrate through the membrane from the solvent chamber into that of the polymer solution and dilute it. Therefore, the volume of the polymer solution increases until an equilibration is reached between the osmotic pressure π_{os} and the hydrostatic pressure generated by the diluted polymer solution

$$\pi_{os} = \sigma \, g \, \Delta h$$

where σ is the density of the solvent and g is the acceleration of gravity. Following Van't Hoff, it is

$$\pi_{os}\, V = nRT$$

for diluted solutions, with V being the volume of the polymer solution and n the number of moles of the dissolved polymer. Since $n = m/M_n$ (m is the mass (in g) of dissolved polymer) and $c = m/V$ it follows that:

$$\pi_{os} = \frac{m}{V}\frac{RT}{M_n} = \frac{cRT}{M_n}$$

Since van's Hoff's law is valid only for infinitely diluted solutions, one develops π_{os}/c in power law series (break after the linear term in c)

$$\frac{\pi_{os}}{c} = \frac{RT}{M_n} + A_2.c$$

Thus, the osmotic pressure is first measured at different polymer concentrations, π_{os}/c is then plotted vs. c, the values are linearly extrapolated to $c \longrightarrow 0$, and the value of M_n is determined from the y axis intercept. A_2 is the second virial coefficient of the osmotic pressure. Solvents where $A_2 = 0$ are called "ideal" solvents. For membrane osmometry (as well as for all other techniques of molecular weight determination via colligative properties) it is very important that the samples to be analyzed are very pure. In particular low-molecular-weight impurities have to be removed reliably. Otherwise, they will migrate through the semi permeable membrane and lower the chemical potential of the solvent in the reference chamber. An overestimation of the molecular weight will follow. The same effect applies when there are very

small oligomers in the test sample. Therefore, the lower limit of M for application of membrane osmometry is approx. 10.000 ~ depending on the available membrane pore size. On the other hand, M should be below approx. 50.000 because of the limited sensitivity of this method. Moreover, complete dissolution and absence of aggregates is required for reliable measurements.

3.2.12.1Method.

The colloid -osmotic pressure is measured by means of an osmotic cell (Osmomat 050). The lower half of the osmotic cell, which is closed off to the outside, is filled with electrolyte containing ringer's solution. The upper half of the cell, which is open to the outside, is filled with a colloid-containing solution. The two halves of the cell are separated from each other by a semi mermbrane. This membrane possesses defined pores, through which only water moleculles migrate through. Due to osmotic pressure differential of the two solutions, solvent permeates from the lower into the upper half of the measuring cell until equilibrium is reached between the pressure in lower half of the cell and the osmolal concentration. An electronic pressure measuring system, which is mounted into the lower half of the cell, transduces the under pressure into an electronic signal, which is shown on a digital display.

3.2.13 Determination of weight average molecular weight

3.2.13.1 Gel permeation chromatography (GPC)

Gel permeation chromatography is, widely, used to determine the molecular mass distribution of macromolecules. Gel permeation chromatography, coupled to and on-line, absolute molecular weight determining device (a laser light scattering photometer) and a concentration sensitive detector (such as refractive index or ultraviolet) are, currently, the best available techniques for the quick and absolute determination of polymers molecular weights and their distribution. The light scattering detector utilizes the principle that the intensity of light scattered elastically by a molecule is, directly, proportional to the molecular weight (mass detector). Using refractive index detector (connected directly after the light scattering) it was possible to measure the molecular weight of each fraction as it clutes from the GPC column. In addition, the use of an ultraviolet (UV) detector at 214 nm, which, specifically, shows the amount of protein in fractionated material, is also possible. The polysaccharide weight averages, Mw, was determined by GPC-MALLS (Gel Permeation Chromatography-Multiangle Laser Light Scattering).The GPC system consisted of an Agilent G1310A pump (Agilent Tecnologies, Santa Clara, USA), an Agilent G1329A auto-injector with an injection loop of 100 µL and a Wyatt 986 refractometer (Wyatt Technology, Santa Barbara, USA).The MALLS apparatus consisted of a Wyatt Dawn-Heleos II laser photometer (Wyatt

Technology, Santa Barbara, USA) equipped with a K5 flow cell and a He–Ne laser operating at k = 632.8 nm. An aqueous SEC column: Shodex OHpak SB-806 HQ (8.0 mm x 300mm) (Showa Denko, Kawasaki, Japan) was used for the analysis. The mobile phase consisted of a filtered (0.22 µm) 0.1 M sodium acetate solution obtained with ultrapure water. The flow rate was 0.5 mL/min and analyses were performed at room temperature. The MALLS instrument was placed directly after the GPC columns and before the refractive index detector (DRI). Prior to measurements, a Dawn apparatus was calibrated using HPLC grade toluene and normalized using a 20nm polystyrene latex standard (Thermo Scientific, Fremont, USA) in 0.1 M sodium acetate. The performance of the HPSEC-MALLS system was checked with monodisperse pullulan of various molecular weights. A dn/dc value of 0.1010 was used. Data were collected from the DRI and MALLS and evaluated with the ASTRA software 5.3.4.14. Since gums are polydisperse polysaccharides, only average weights were compared. Results were estimated using second-order Zimm.

3.2.13.2 Sample preparation

1.0 mg/ml gum samples was prepared (based on dry weight) and dissolved in 0.1 M sodium acetate solution and hydrated by roller (SRT9.Stuart Scientific, Malaysia) mixing the solution overnight to ensure that sample fully dissolved and hydrated. The solutions were then centrifuged for 10 minutes. The gum

solutions were then filtered using (0.45 µm) to eliminate dust particles prior to injection into the GPC-MALLS system.

3.2.14 Determination of emulsion stability.

Three types of refined oil groundnut, sesame and corn oil .and 2% aqueous gum solution were used to prepare stock emulsions. Emulsions were prepared by blending a measured amount of the gum solution (20%) and the oil(2:1 v/v)for one minute at 1800 rpm using kitchen blender (triplicate preparations were used Karamalla *et al.*, 1998).Aliquot (1Ml)of the stock dilution of 1/1000. The absorbance was then read at 520nm in spectrophotometer. Another reading of absorbance was recorded after an hour Emulsion stability was calculated as: Emulsion stability = First reading of absorbance / Reading of absorbance after an hour Test for stability under influence of emulsion factors: these tests were done with the objective of studying effect of emulsification factors of stirring time, concentration and gum grade on emulsion stability.

1- Stirring time: this test was done to study the effect of the length of stirring on emulsion stability. One ml of the stock emulsion was diluted with distilled water to a concentration of 1/1000 and then stirred for different time (1, 2, 3, 4, and 5 days). Emulsion stability was determined following the previous procedure.

2- Concentration: distilled water diluted concentration of stock emulsion of 1, 2, 3 and 4/1000 were prepared and examined for emulsion stability under a

fixed stirring time of one minute at room temperature. Emulsion stability was measured as before.

3- Gum grade: Emulsion was prepared by blending 20%agueous gum solution and corn oil of 2:1 Determination of emulsion stability was done following the method described by Karamalla *et al.* (1998) .

3.2.15 Total phenol content (TPC)

The determination of antioxidant activity through TPC was carried out according to the method of (Musa *et al*., 2011). About 100 µL *Albizia Amara gum* was added with 0.4 ml distilled water and 0.5 ml diluted Folin-Ciocalteu reagent. The samples (*Albizia Amara gum* with Folin-Ciocalteu reagent) were left for 5 min before 1 ml 7.5% sodium carbonate (w/v) was added. The a absorbance's were taken at 765 nm wavelength with spectrophotometer after 2 h. Calibration curve of Gallic acid was set up to estimate the activity capacity of samples. The result was expressed as mg of Gallic acid equivalents/100 g of fresh sample (mg GA/100 g of FW)

3.2.16 Ferric reducing antioxidant power (FRAP)

The determination of antioxidant activity through FRAP was carried out according to the method of Musa *et al*. (2011). FRAP reagent was prepared fresh as using 300 mM acetate buffer, pH 3.6 (3.1 g sodium acetate tri hydrate, plus 16 mL glacial acid made up to 1:1 with distilled water); 10 mM TPTZ (2,4,6-tris (2-pyridyl)-*s*-triazine), in 40 mMHCLl; and 20 mM$FeCl_3$•6H2O in the ratio of

10:1:1 to give the working reagent. About 1 ml FRAP reagent was added to 100 μL *Albizia Amara gum* and the absorbance's at 595 nm were measured capacity. after 30 min. Calibration curve of Trolox was set up to estimate the activity capacity of samples. The result was expressed as mg of Trolox equivalents per 100 g of fresh sample (mg TE/100 g of FW).

3.2.17 ABTS assay:

The ABTS radical cation was generated by the interaction of ABTS (250 μM) and $K_2S_2O_8$ (40 μM). After the addition of 990 μL of ABTS solution to 10 mL of *Albizia Amara gum* or Trolox standard (final concentration of 0-20 μM) in methanol or 20 mM acetate buffer (pH 4.5), the absorbance at 734 nm was monitored. The percentage decrease of the absorbance was calculated and plotted as a function of the concentration of *Albizia Amara gum* and Trolox for the standard reference data (Özgen *et al*., 2006). The following formula was used: Percentage (%) of reduction power = $A_{blank} - A_{sample} / A_{blank} \times 100$.

Where A is the absorbance.

3.2.18. Partial specific volume of solvent

Tangent method will be used (Tager, 1978) by dissolving a constant weight of gum sample in different weights of solvent (water). The density of solution will be calculated and then the total volume of the solution is determined. Then volume of solution was plotted against weight of solutions. The partial specific volume of water is equal to the $\partial v / \partial g$ will be found from graph slope.

3.2.19. Partial specific volume of the gum

The same is used (Tangent method) where different weights of gum were dissolved in a constant weight of water.

3.2.20. Osmotic pressure

Osmotic pressures of gums solutions were measured using osmotic cell (Osmomat 050, colloidal osmometer) at 25 C°. five to eight different concentrations of each sample were prepared and used to determine the osmotic pressures of samples.

Chapter Four

Results and discussions

The characterization of physicochemical properties of commercial gums is very important when we need to use the gum in the industrial applications. The purposes study of chemical, physical, emulsion stability and thermodynamic properties of Albizia *amara* gum samples, are to ensure the purity of the gum, to avoid used of mixed samples and to know the specifications of the samples under study. Table (4.1 ,4.2 and 4.3) summarize the results of analytical data of exudate gum of *Albizia Amara* gums collected from central and west Darfur.

4.1 Moisture content

The moisture content of the gum is usually affected by the season of collection, the prevailing climate condition and storage condition. The moisture content of *Albizia amara* gum samples collected in season 2012-2013from Central Dar fur, ranged between 10.50-14.10% with an average value of 12.14%. *Albizia amara* gum samples of season 2012-2013 from west Darfur had moisture content in the range of 10.68-13.30 with an average value of 12.71. The moisture content of *Albizia amara* gum samples collected in season 2014which were found to fall in the range of 11.77-13.86 with an average value of 13.10 .The results show less contents compared to those reported by (Mahinzi 2002).

Table (4-1) Physicochemical properties of *Albizia Amara* Gum from Central Darfur season 2012 -2013

State	Sample	Moisture%	Ash %	pH	Refractive index	Nitrogen %	Protein%	Acid equivalent	Uronic acid
Central Darfur	SCD1-12	12.30	2.53	4.90	1.33543	0.41	2.71	1670	11.62
Central Darfur	SCD 2-12	11.86	2.10	3.95	1.33123	0.33	2.18	1721	11.28
Central Darfur	SCD 3-12	13.01	3.56	4.25	1.33878	0.39	2.57	1734	11.19
Central Darfur	SCD 4-12	10.50	2.01	3.80	1.33657	0.34	2.24	1719	11.29
Central Darfur	SCD 5-12	11.95	3.22	4.18	1.33432	0.39	2.57	1699	11.42
Comp- SCD 2012		11.25	2.73	3.83	1.33453	0.42	2.77	1687	11.50
Central Darfur	SCD 1-13	10.65	3.43	4.15	1.33675	0.43	2.84	1702	11.40
Central Darfur	SCD 2-13	12.80	2.04	3.82	1.33759	0.25	1.65	1722	11.26
Central Darfur	SCD 3-13	14.10	3.05	4.30	1.33887	0.44	2.90	1649	11.76
Central Darfur	SCD 4-13	11.44	2.43	4.45	1.33378	0.41	2.71	1701	11.41
Central Darfur	SCD 5-13	12.87	2.13	4.74	1.33389	0.38	2.51	1744	11.12
comp- SCD 2013		13.12	2.73	4.20	1.33374	0.42	2.77	1698	11.43
Whole comp-kk		11.93	2.17	3.56	1.33587	0.37	2.44	1678	11.56
Mean		12.14	2.63	4.14	1.33588	0.38	2.55	1701	11.40
Std-Deviation		1.04	0.55	0.38	0.0023	0.05	0.38	26.61	0.18

Table (4-2) Physicochemical properties of *Albizia Amara* Gum from West Darfur season 2012 -2013

State	Sample	Moisture%	Ash %	pH	Refractive index	Nitrogen %	Protein%	Acid equivalent	Uronic acid
West Darfur	SWD1-12	12.77	3.01	3.70	1.33878	0.39	2.57	1723	11.25
West Darfur	SWD 2-12	13.01	2.61	3.89	1.33189	0.34	2.24	1644	11.80
West Darfur	SWD -12	10.68	3.14	4.39	1.33878	0.40	2.64	1750	11.10
West Darfur	SWD 4-12	11.64	2.20	4.13	1.33759	0.42	2.77	1739	11.19
West Darfur	SWD 5-12	13.30	2.41	3.90	1.33868	0.33	2.18	1698	11.43
Comp-2012		13.21	2.89	4.50	1.33848	0.34	2.24	1666	11.64
West Darfur	SWD 1-13	12.42	3.34	4.46	1.33759	0.26	1.72	1687	11.50
West Darfur	SWD 2-13	12.93	2.36	3.43	1.33729	0.43	2.84	1722	11.27
West Darfur	SWD 3-13	12.99	1.80	4.20	1.33838	0.42	2.77	1693	11.46
West Darfur	SWD 4-13	13.09	3.07	4.36	1.33779	0.28	1.85	1746	11.11
West Darfur	SWD 5-13	13.05	2.49	3.76	1.33819	0.33	2.18	1589	11.21
Comp2013		13.11	2.26	3.81	1.33834	0.42	2.77	1776	10.92
Whole com- SWD		13.05	3.18	4.39	1.33856	0.41	2.71	1735	11.18
mean		12.71	2.67	4.07	1.34	0.37	2.39	1705	11.31
Std-Deviation		0.75	0.47	0.34	0.05	0.06	0.37	50.50	0.24

Table (4.3) Physicochemical properties of *Albizia amara* Gum from season 2014

State	Sample	Moisture%	Ash %	pH	Refractive index	Nitrogen %	Protein%	Acid equivalent	Uronic acid
Central Darfur	SCD 1-14	13.86	2.33	4.76	1.33543	0.39	2.60	1746	11.25
Central Darfur	SCD 2-14	12.48	2.41	4.69	1.33123	0.44	2.90	1723	11.11
Central Darfur	SCD 3-14	12.68	2.14	4.89	1.33878	0.40	2.64	1589	11.21
Central Darfur	SCD4-14	13.01	2.56	4.63	1.33657	0.42	2.77	1701	11.41
West Darfur	SWD 1-14	12.02	1.98	4.55	1.33432	0.34	2.24	1595	11.91
West Darfur	SWD 2-14	12.15	2.54	4.76	1.33453	0.38	2.51	1773	11.18
West Darfur	SWD 3-14	11.77	2.19	4.99	1.33675	0.41	2.71	1693	11.46
West Darfur	SWD 4-14	12.99	3.33	3.68	1.33759	0.389	2.57	1722	11.25
Wholcomp-14		12.95	2.31	4.43	1.33887	0.44	2.90	1741	11.42
Mean		12.48	2.05	4.60	1.33588	0.40	2.65	1698	11.36
Std-deviation		0.97	0.75	0.36	0.0023	0.030	0.19	61.01	0.23

4.2 Ash content

The ash mean content value of *Albizia amara* gum samples of season 2012-2013,and 2014 the mean value were found to be 2.63,2.67 and 2.28 which disagree with the results mentioned in the literature review (Mhinzi 2002)

4.3 pH value

The mean pH values *Albizia amara* gum samples under investigation from season 2012, 2013 and 2014 were found to be 4.14, 4.07and 4.99, respectively .The pH values of *Albizia amara* obtained in this work agrees with those reported by Mhinzi(2002).

4.4 Acid equivalent weight and uronic acid

The mean acid equivalent weight values of the *Albizia amara* samples shown in Tables 4.1, 4.2 and 4.3.For the season's 2012-2013and 2014 were found to be 1701, 1705 and 1698, respectively. The mean uronic acid content values for the seasons 2012, 2013 and 2014 were found to be 11.40, 11.31 and 11.36, respectively. The mean acid equivalent weight and uronic acid values of Albizia *amara* obtained in this work agree with thoseof 1724 and 11.25 respectively. Agree with reported in the literature Mhinzi(2002).

4.5 Refractive index

The mean refractive index values for *Albizia amara* gum samples for seasons 2012, 2013 and 2014 were found to be 1.33588, 1.33856 and 1.3358 respectively. The statistical analysis of result shows that there is no effect of location in the standard deviation (σ) values of the refractive index.

4.6Nitrogen content and protein content

The nitrogen and protein content using kjeldahl method for the season s 2012, 2013 and 2014 respectively. The mean percentage of nitrogen and protein content ranged between 0.38, 0.37 and 0.41 respectively for all season. The protein content was calculated from the Nitrogen content by using the Anderson factor found to be 6.6.for the protein content result of *Albizia amara* gum shows the mean percentages of all season from all location range 2.55,239 and 2.65%. The result obtained is similar reported in the literature Mhinzi (2002.

4.7 Intrinsic viscosity

The intrinsic viscosity of composite samples of *Albizia amara gum* samples (comp) Figure (4.1, 4.2, 4.3and 4.4) fall between 17.70-21.66 $ml.g^{-1}$ with an average value of 19.64 $ml.g^{-1}$.

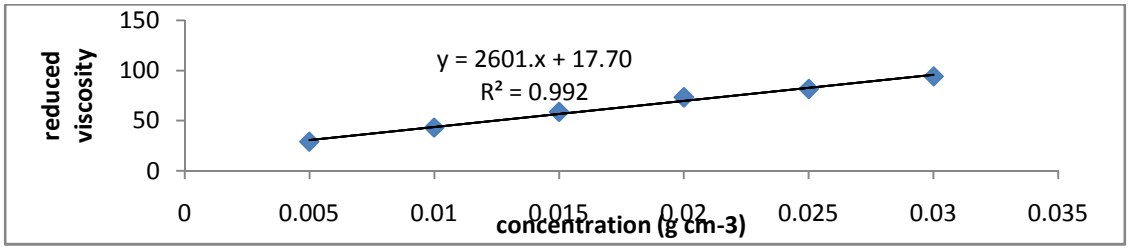


Figure (4.1) variation of reduced Viscosity. With concentration (comp1)

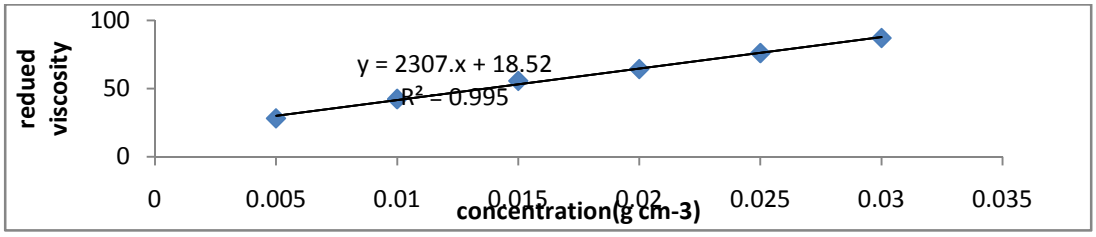


Figure (4.2) variation of reduced Viscosity. With concentration (comp2)

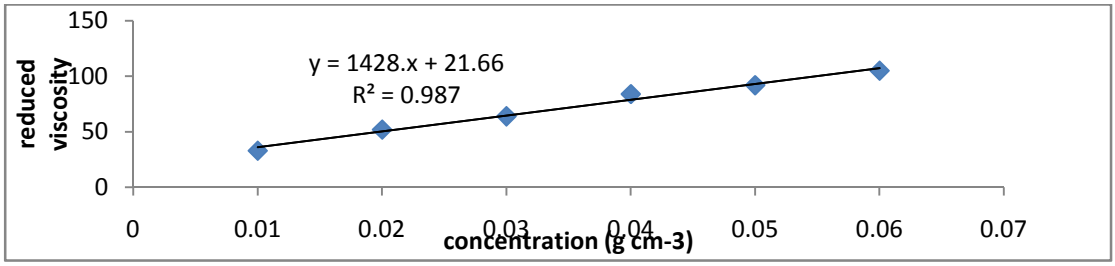


Figure (4.3) variation of reduced Viscosity. With concentration (comp3)

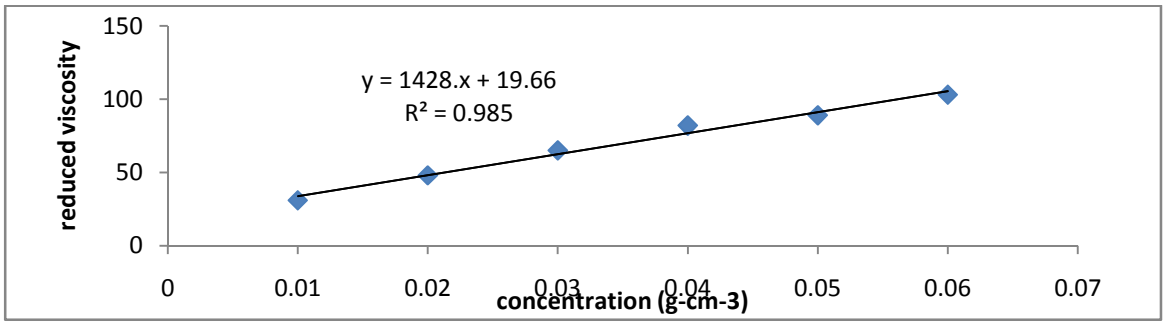


Figure (4.4) variation of reduced Viscosity. With concentration (comp4)

4.8 Specific optical rotation

The specific optical rotation is regarded as one of the analytical parameters by means of which gum species can be distinguished from other gums species. *Albizia amara* has a negative specific optical rotation and belongs to vulares series the contains *A. Senegal*. *A.Leata*. *A.polyacantha*, *Amellifer*a…etc. The specific optical rotation of *Albizia amara* gum samples were found to be between -21.33^0,-21.75^0, 21.50^o, and -20.90^0. The mean values of specific optical rotation of *Albizia amara* gum samples were found -21.12^o.

4.9 Sugar content

The sugar content of *Albizia amara* gum were measured using HPLC technique in Khartoum university and were found to be 21.66% arabinose , 4.25 galactose and 8.75 rhamnose (Table 4.4). The arabinose had a higher percentage than galactose and the lowest percentage of rhamnose .

4.10 Density of solid gum

The Density of solid gum of the *Albizia amara gum samples* studied fall between$1.41gcm^{-3}$and$1.51gcm^{-3}$ with an average value of $1.46gcm^{-3}$ the highest value of intrinsic viscosity of $1.51gcm^{-3}$ was that of sample $comp_1$.

4.11 Number average molecular weight

The number average molecular weight of *Albizia amara* samples, under study, was determined by osmometery measurement is shown in Table (4.4)The number average molecular weight of *Albizia amara* samples ranged between $4.602 \times 10^5 - 4.86 \times 10^5$ g.mol^{-1} with an average value of 4.673×10^5 g.mol^{-1}.

4.12 Refractive index increment *(dn/dc)*

The refractive index increment of *Albizia amara* gum samples show in figure (4.8) and was found to be 0.101.

4.13 Molecular weight

The molecular weight was measured for the whole gum and as one peak define as (Ls, UV, DP and RI).the elution profiles of *Albizia amara* gum using multi –angle laser light scattering (MALLS) is given in Figure (4.1) the figure show elution profile as indicated by detectors measuring refractive index, light scattering at 90^o and UV at 214nm.the light scattering respond reflects the mass and concentration .the refractive index (RI), concentrated detector response of the total mass. The summary of the molecular weights parameter of all *Albizia amara* samples gum given table (4.6) .the result shows that number average

molecular weight and molecular weight between $4.04911x10^5$ to $5.637x105x10^5$ respectively.

Table (4.4) physicochemical properties of *Albizia Amara* Gum

sample	Rahamanose%	Arabinose%	Galactose %	Optical rotation	Intrinsic viscosity	Molecular weight(Mn)	Density
Comp1	9	23	5	-21.33^0	17.70 cm^3/g	$4.602x10^5$	1.51 gcm^{-3}
comp2	8	22	5	-21.75^0	18.82 cm^3/g	$4.731x10^5$	1.45 g cm^{-3}
comp3	9	21	3	-21.5^0	21.66 cm^3/g	$4.731x10^5$	1.41 g cm^{-3}
comp4	9	21	4	-20.9^0	19.66 cm^3/g	$4.865x10^5$	1.48 gcm^{-3}
Average	8.75	21.75	4.25	-21.12^0	19.64 cm^3/g	$4.673x10^5$	1.46 g cm^{-3}

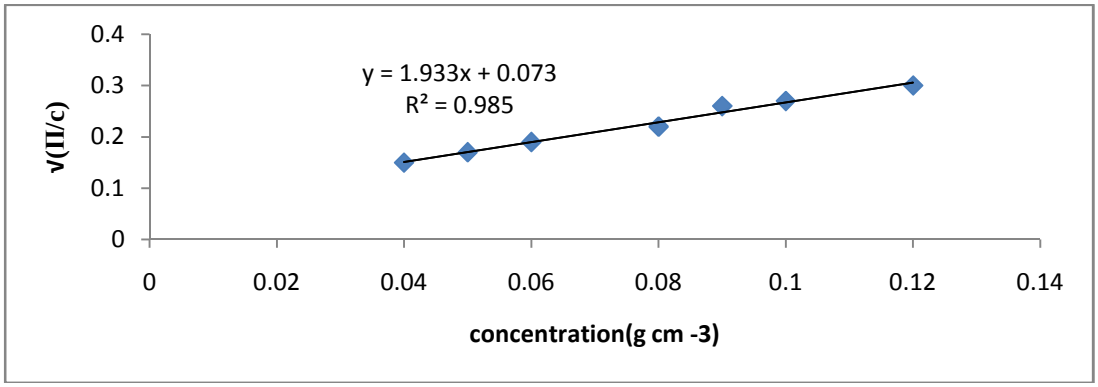


Figure (4.5) Number average molecular weight of *Albizia amara* gum (comp1).

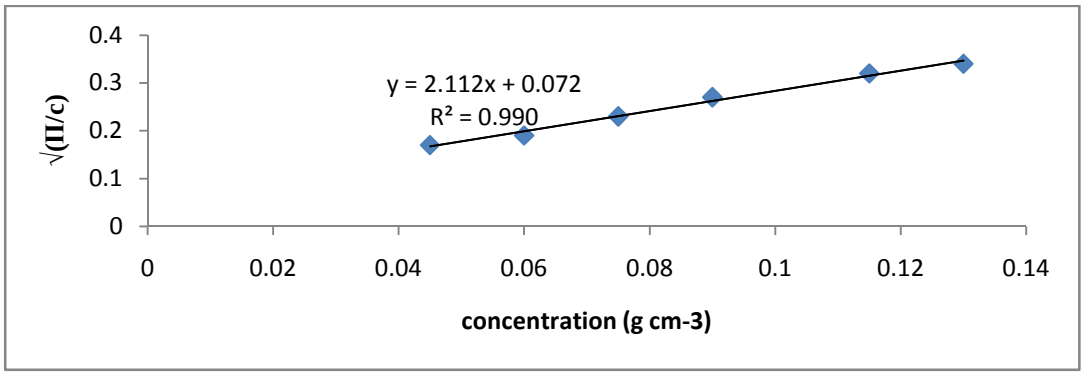


Figure (4.6) Number average molecular weight of *Albizia amara* gum (comp2).

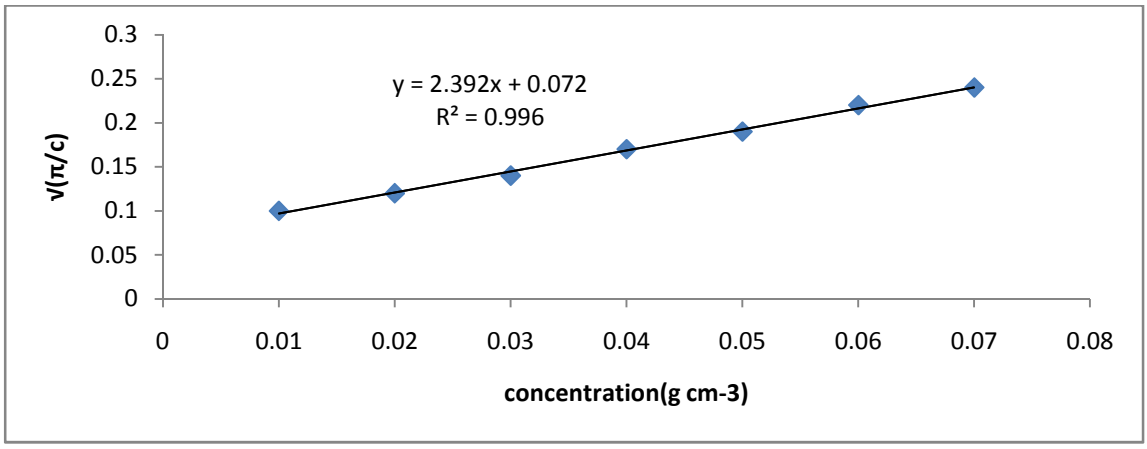


Figure (4.7) Number average molecular weight of *Albizia amara* gum (comp3).

Table (4.5) **Molecular weight average of *Albizia amara* gum samples**

Sample	Mn		Mw
	Osmotic pressure method	GPC methods	GPC methods
A.seyal **Malik(2008)**	**$4.7x10^5$**	**$5.16x10^5$**	**$15.50x10^5$**
A.senegal **Malik (2008)**	**$2.4x10^5$**	**$2.86x10^5$**	**$8.64x10^5$**
A.polyacantha malik**(2008)**	**$1.9x10^5$**	**$1.43x10^5$**	**$3.18x10^5$**
A.nilotica var . Amira (2011)	**2.00x107**	**1.90x106**	**$3.58x10^6$**
This study2014	**$4.673x10^5$**	**$4.04911x0^5$**	**$5.637x10^5$**

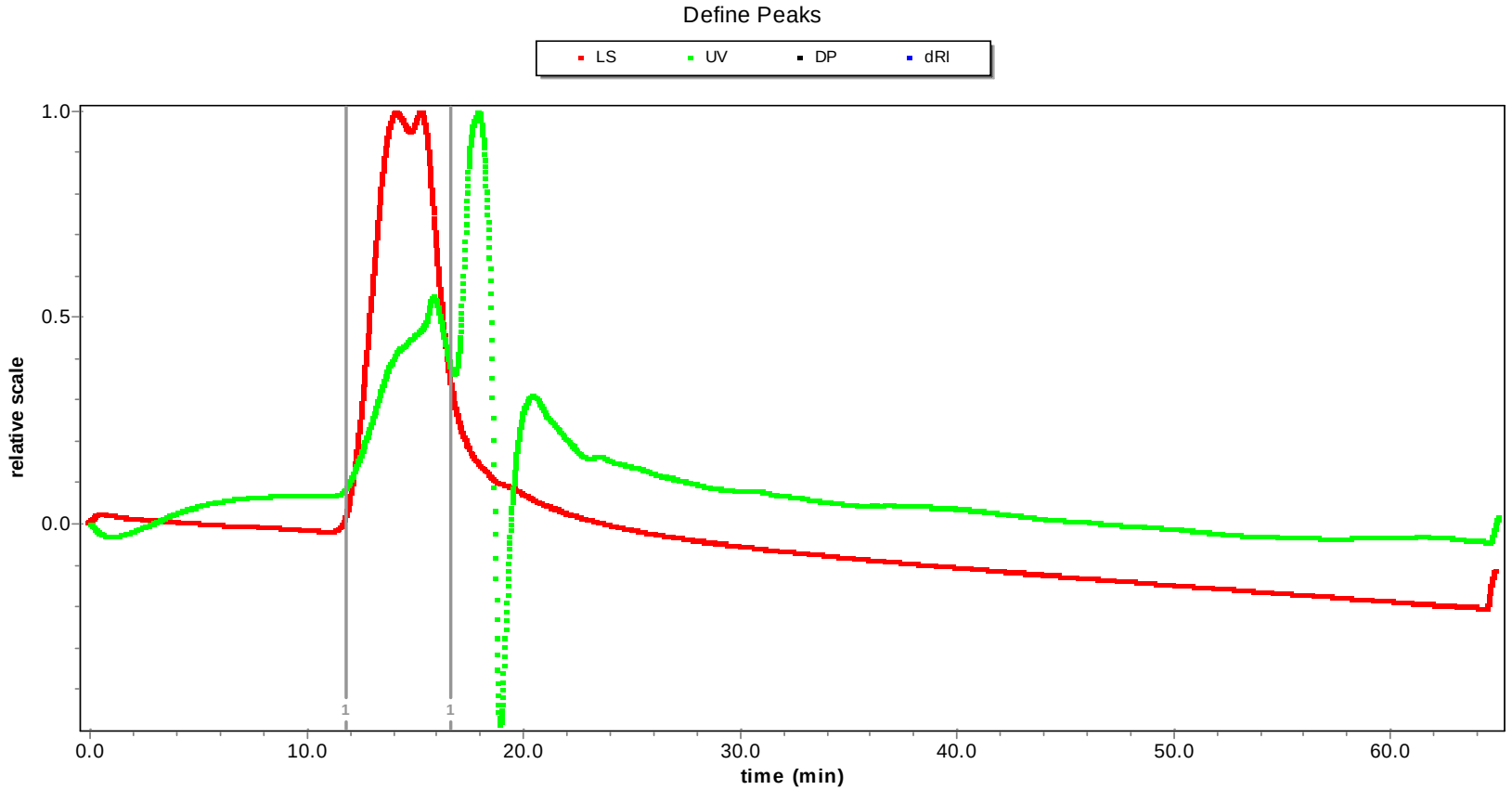


Figure (4.8) GPC elusion profile of molecular weight and Number average molecular weight

4.14 Cationic composition

Minerals composition of the samples was determined (using atomic absorption spectrophotometer) and the average values were shown in Table (4.5) the major element in the order: Ca, Mg, Fe, Cu, Mn , Na, Zn, Cd, . Calcium, magnesium and Iron recorded high values, indicating that the gum is a salt of calcium, magnesium and Iron.

Table (4.5) Cationic composition of *Albizia amara* Gum

Element	ppm	ppm	Average ppm
Ca	7971	4256	6113.5
Mg	2558	1600	2079
Fe	292	61.45	176.725
Cu	85	104	94.5
Mn	0.04	75.145	37.7725
Na	0.07	40	20.035
Zn	8	2.872	5.436
Cd	0.15	0.079	0.1145

4.15Emulsion stability

Table (4.7) shows the result obtained from *Albizia amara* gum samples of Emulsion stability. That emulsion prepared by mixing pure oils (groundnut, sesame and corn oil) .with aqueous solution of gums (20%) had stabilities varied between (0.9968-1.1864) of groundnut, (0.9595-1.2631) of sesame and

(1.1137-1.3076) of corn oil. Found the mean values 1.09245, 1.10175 and 1.22525 respectively (Fig.4.11). However, result indicated that using different types of oil resulted insignificant difference in emulsion stability.comp4 showed lowest stability oils (0.9968, 0.9595 and 1.1137) respectively. While that of comp2was the highest (1.1864, 1.2631 and 1.3076). Difference in emulsion stability may be ascribed to difference in protein content. Protein is the fraction that provides the functionality of the gum as emulsion stabilizer. Therefore the emulsion capacity and emulsion stability in regard to coalescence and flocculation were recorded in gums with highest nitrogen content (Dickinson *et al*., 1991) .variability in ES with varied oil type was reported (Pearce and Kinsella, 1978).

Concentration: Fig (4.10) illustrates stability of emulsions with concentration 1, 2.3and 4/1000 of *Albiziz amara* gum samples. Data reveal an insignificant increasing in magnitude. On the other hand, stability of emulsion decreases from 1 to 5 days of Emulsion stability (Fig.4.11). Mechanical blending and homogenization affects droplet-size distribution and hence influences the properties of an emulsion (Brosel and Schubert, 1999). Droplets can be made smaller by applying more intense emulsification resulting in more stability (Walstra, 1996).

Table (4.7) Emulsion stability of *Albizia amara* gum samples using different oil

Sample	groundnut	Sesame	Corn oil
comp1	1.0421	1.0492	1.2162
comp2	1.1864	1.2631	1.3076
comp3	1.1445	1.1352	1.2635
comp4	0.9968	0.9595	1.1137
Average	1.0925	1.1018	1.2253

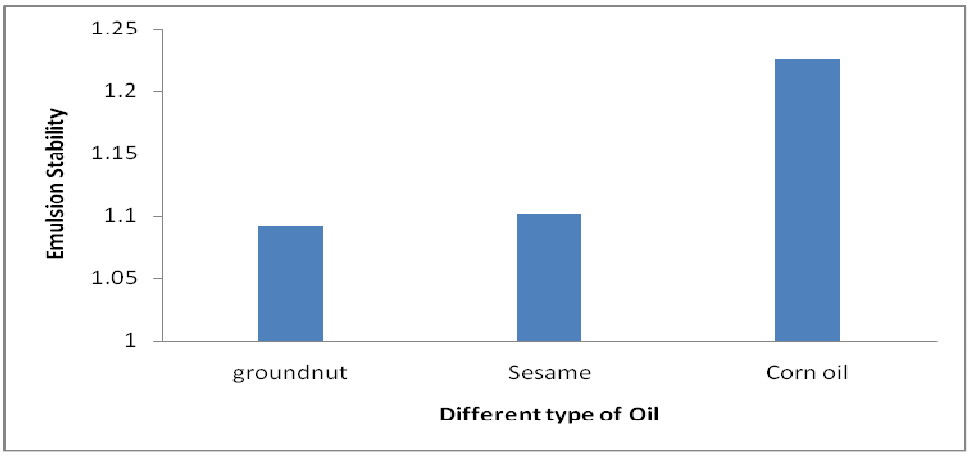


Figure (4.9) variation Emulsion solubility of the *Albiziza amara* gum with the type of oil

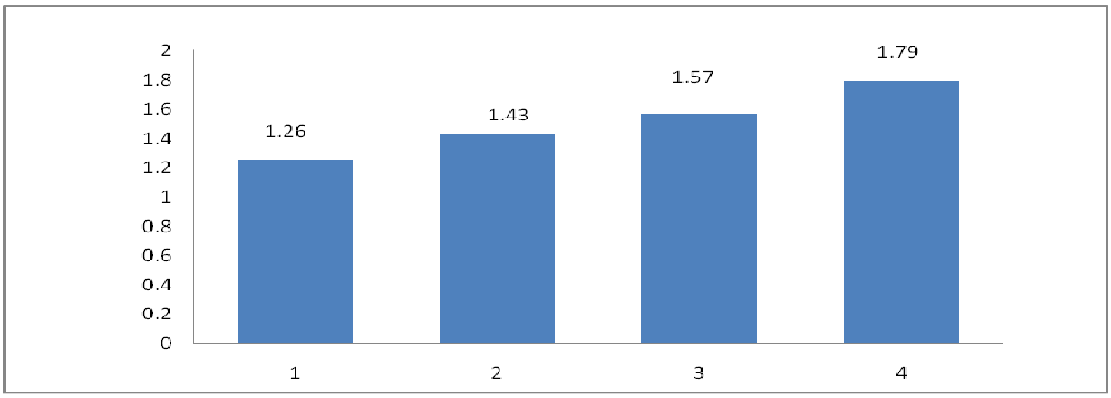


Figure (4.10) variation Emulsion solubility of the *Albiziza amara* gum with varying concentration

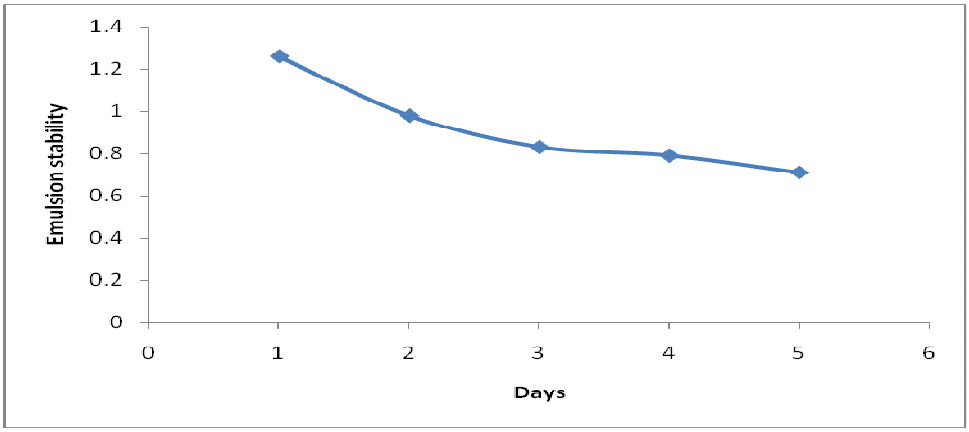


Figure (4.11) Variation Emulsion of the *Albiziza amara* gum with time

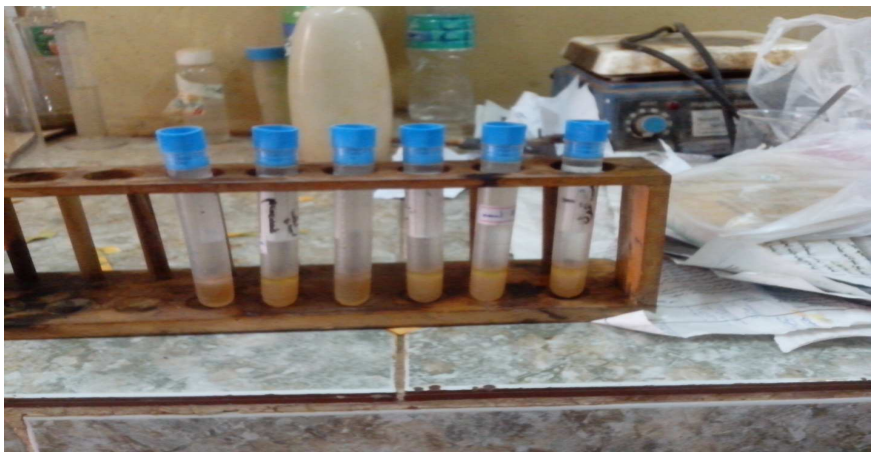


Figure (4.12) Prepration samples of *Albizia amara* gum for stability Emulsion

4.16 Antioxidant of *Albizia amara* gums

The antioxidant capacity composition samples of *Albizia amara gum* was evaluated by three different methods,(Table4.8) including Total phenol content ,TPC ferric Reducing Antioxidant power, FRAP and ABTS. The Antioxidant gum of TPC of the *Albizia amara gum samples* studies fall between12.80, 19.60 (mg/100g) with an average value of 18.3(mg/100g) the highest value of TPC 19.60 (mg/100g) was that of sample $comp_2$. also antioxidant of FRAP. Had been found between 39.20(mg/100g), 165.50 (mg/100g) with an average

101.9(mg/100g). Fig (4.14) samples under investigation from ABTS antioxidant were found to be between 20.12% - 30.80%. The mean values were found to be 25.95%.Based on TPC, FRAP and ABTS estimated, *Albizia amara* gum samples had the highest percentage of antioxidant activity from FARAP and TPC had the lowest.

Table (4.8) Antioxidant activities of *Albizia amara* gum samples

sample	TPC(mg/100g)	FRAP(mg/100g)	ABTS (%)
comp1	22.20	114.27	27.11
comp2	19.60	88.63	25.78
Comp3	12.80	39.20	20.12
Comp4	18.60	165.50	30.80
Average	18.3	101.9	25.95

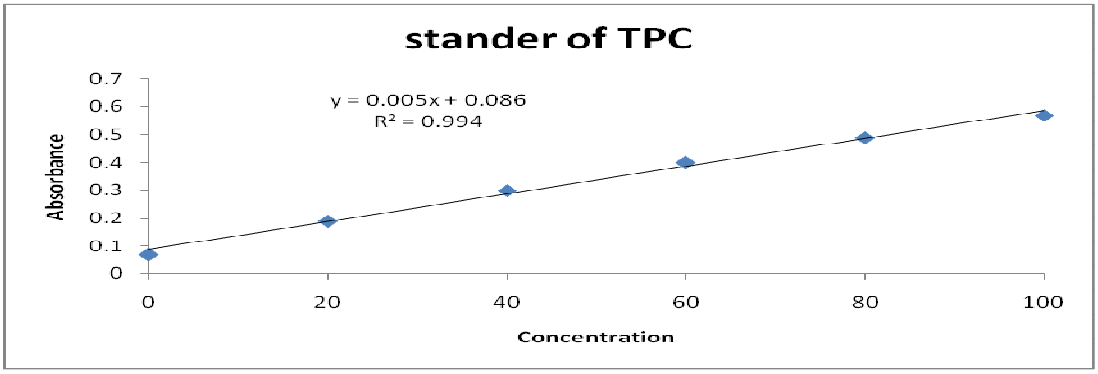


Figure (4.13) TPC standards absorbance curve

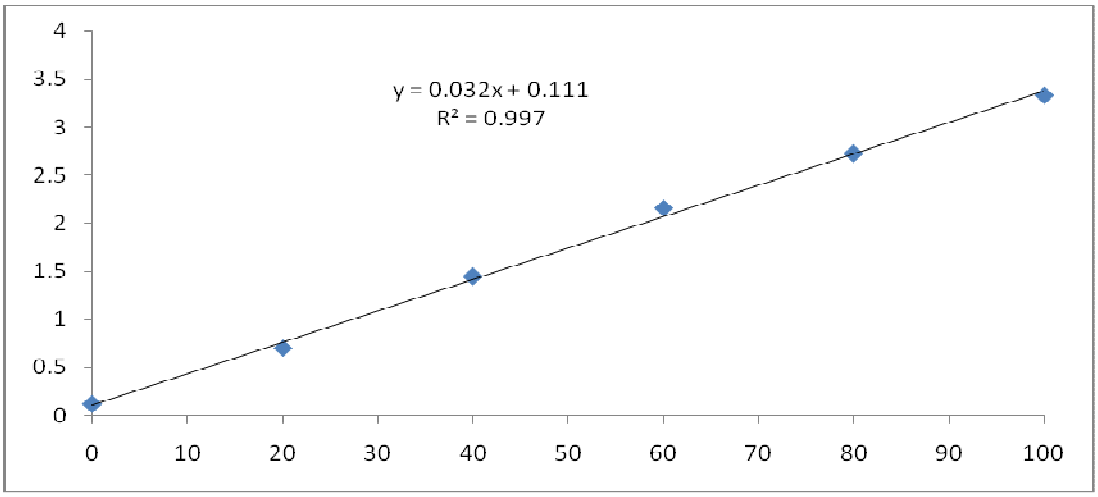


Figure (4.14) *Albizia amara* gum sample of Standard of FARAP

Figure (4.15) *Albizia amara* gum sample carrier for Antioxidant Analysis

4.17 *Albizia amara* gum thermodynamic properties

Show the data of specific in Tables 4.9 to 4.12 and Figures 4.16 to 4.21 and from the intercepts of these figures, partial specific volumes of solvent and solute were obtained *Albizia amara* gum in *Albizia amara* gum solutions (comp 2012, comp 2013, and comp 2014) were found to be 1.001 cm^3g^{-1} - 0.665cm^3g^{-1} , 1.002 cm^3g^{-1} - 0.668cm^3g^{-1} and 1.023 cm^3g^{-1} - 0.669cm^3g^{-1} respectively. The results show insignificant of partial specific volumes of *Albizia amara* gum. The volumes fractions of water ϕ_1 and gums ϕ_2 in gums solutions were calculated using equations (2.18.4.1 and 2.18.4.2) section (2.18.4) as tabulated in Table (4.9). Comp 2013 has the highest water fraction followed by comp 2012 last comp 2014 for the gum fraction comp 2014 has highest gum fraction followed by comp 2013 and comp 2012. The sequence of the volume fraction was related to the sequence of weight average molecular weight and partial specific volume of samples gums studied. The second virial coefficient (A_2) determined using Van`t Hoff equation and found to be $0.36x10^{-5}$. Table 4.10, 4.11 and 4.12 show Osmotic pressures of different concentration of comp 2012, comp 2013 and comp 2014. According to equation (2.18.6.11) section 2.18.6, it was possible to determine the chemical potential of water as a solvent in different gums solution (Table 4.10, 4.11 and 4.12).

Table (4.9) Volume fraction of water (Φ_1) and *Albizia amara* gum (Φ_2) in *Albizia amara* gum solution.

Sample	Water fraction Φ_1	Gum fraction Φ_2
Comp2012	0.6008	0.3991
Comp 2013	0.6118	0.3889
Comp2014	0.600	0.4000
Average	0.6042	0.396

Table (4.10) Partial specific volumes of water ($\overline{V}$), osmotic pressure (π), chemical potential ($\Delta\mu_1$) and the weight fractions of water (ω_1) and gum (ω_2)in *Albizia amara* solution comp 2012.

Conc.gcm^{-3}	$\overline{V}$ **Cm^{3}g^{-1}**	**π mmHg**	**$\Delta\mu_1$ mmHg.cm^{3}g^{-}**	**$\Delta\mu_1$ j g^{-1}**	ω_1 **g**	ω_2 **g**	ω_1/ω_2
0.02	1.001	5.5	-5.5055	-0.73377304x10^{-3}	0.98	0.02	49
0.04	1.001	6.6	-6.6066	-0.880527648 x10^{-3}	0.96	0.04	24
0.06	1.001	17.1	-17.1171	-2.281367088 x10^{-3}	0.94	0.06	15.67
0.08	1.001	29.2	-29.2292	-3.89566776 x10^{-3}	0.92	0.08	11.5
0.10	1.001	45.2	-45.2452	-6.030280256 x10^{-3}	0.9	0.10	9.0
0.12	1.001	56.2	-56.2562	-7.497826336 x10^{-3}	0.88	0.12	7.33
0.14	1.001	76.90	-78.9769	-10.52935826 x10^{-3}	0.86	0.14	6.143

Where $\overline{V}$ cm^{3}g^{-1} is partial specific volume of water in a gum solution and ω_1 and ω_2 are weight fraction of water and gum respectively.

Table (4.11) Partial specific volumes of water ($\overline{V}$), osmotic pressure (π), chemical potential ($\Delta\ \mu_1$) and the weight fractions of water (ω_1) and gum (ω_2)in *Albizia.amara* Solution 2013.

Conc.gcm^{-3}	$\overline{V}$ Cm^{3}g^{-1}	π mmHg	$\Delta\mu_1$ mmHg.cm^{3}g^{-1}	$\Delta\mu_1$ j g^{-1}	ω_1 g	ω_2 g	ω_1/ω_2
0.03	1.002	8	-8.016	-0.1340816 x10^{-3}	0.97	0.03	32.33
0.045	1.002	11.85	-11.8737	-1.582526736 x10^{-3}	0.95	0.045	21.11
0.06	1.002	20	-20.04	-2.6709312 x10^{-3}	0.94	0.06	15.67
0.075	1.002	31	-31.062	-4.13994336 x10^{-3}	0.925	0.075	12.33
0.09	1.002	35	-35.07	-4.6741296 x10^{-3}	0.91	0.09	10.11
0.115	1.002	54	-54.108	-7.21151424 x10^{-3}	0.885	0.115	7.70

Where $\overline{V}$ cm^{3}g^{-1} is partial specific volume of water in a gum solution and ω_1 and ω_2 are weight fraction of water and gum respectively.

Table (4.12) Partial specific volumes of water ($\overline{V}$), osmotic pressure (π), chemical potential ($\Delta\ \mu_1$) and the weight fractions of water (ω_1) and gum (ω_2) in *Albizia.amara* solution comp2014 .

Conc.gcm^{-3}	$\overline{V}$ Cm^{3}g^{-1}	π mmHg	$\Delta\mu_1$ mmHg.cm^{3}g^{-1}	$\Delta\mu_1$ j g^{-1}	ω_1 g	ω_2 g	ω_1/ω_2
0.01	1.023	2	-2.046	-0.27269088 x10^{-3}	0.99	0.01	99
0.02	1.023	4	-4.092	-0.54538176 x10^{-3}	0.98	0.02	49
0.03	1.023	7.3	-7.4679	-0.995321712 x10^{-3}	0.97	0.03	32.33
0.04	1.023	12.6	-12.8898	-1.717952544 x10^{-3}	0.96	0.04	24
0.05	1.023	15.7	-16.0611	-2.140623408 x10^{-3}	0.95	0.05	19
0.06	1.023	20.45	-20.92035	-2.788264248 x10^{-3}	0.94	0.06	15.67
0.07	1.023	29.95	-30.63885	-4.083545928 x10^{-3}	0.92	0.08	11.5

Where $\overline{V}$ cm^{3}g^{-1} is partial specific volume of water in a gum solution and ω_1 and ω_2 are weight fraction of water and gum respectively.

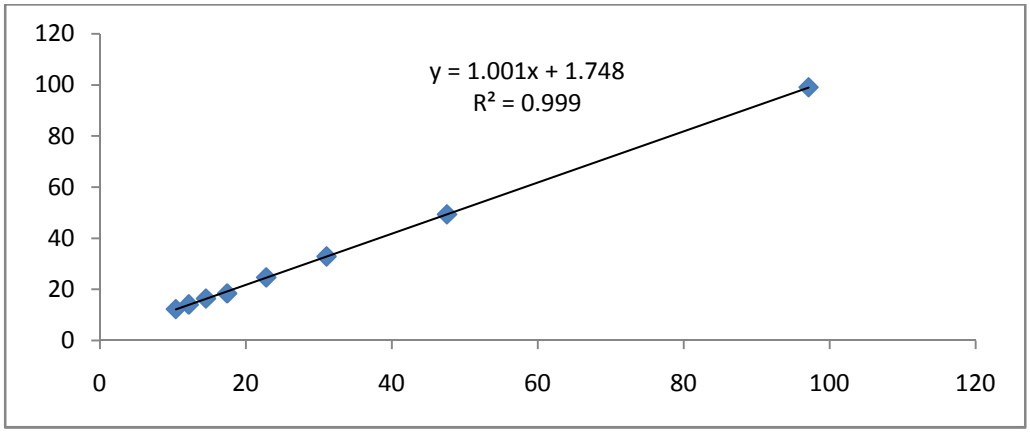


Figure (4.16) Partial specific volume of water in *Albizia amara* gum solutions comp2012.

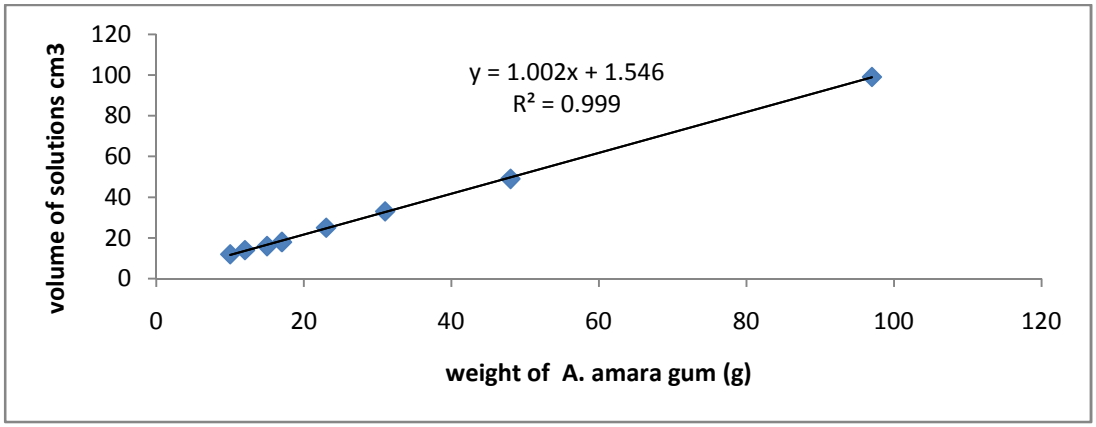


Figure (4.17) Partial specific volume of water in *Albizia amara* gum solutions comp2013

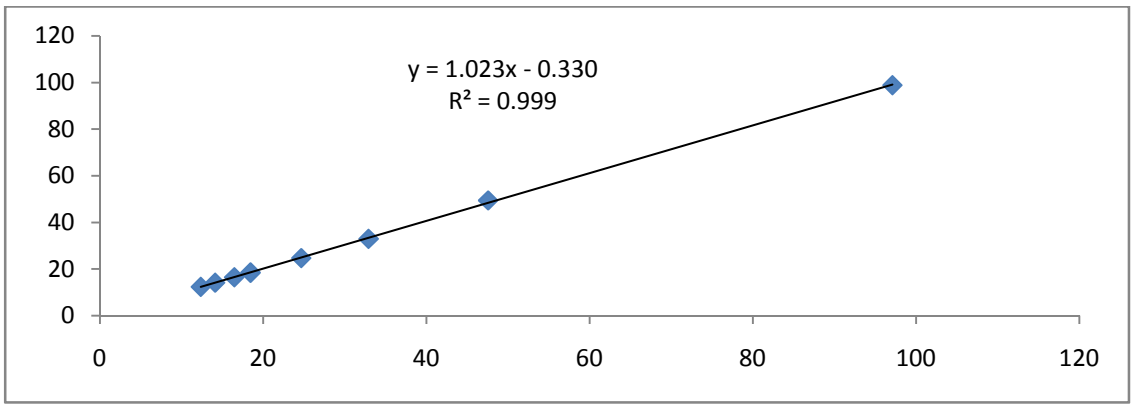


Figure (4.18) Partial specific volume of water in *Albizia amara* gum solutions comp2014.

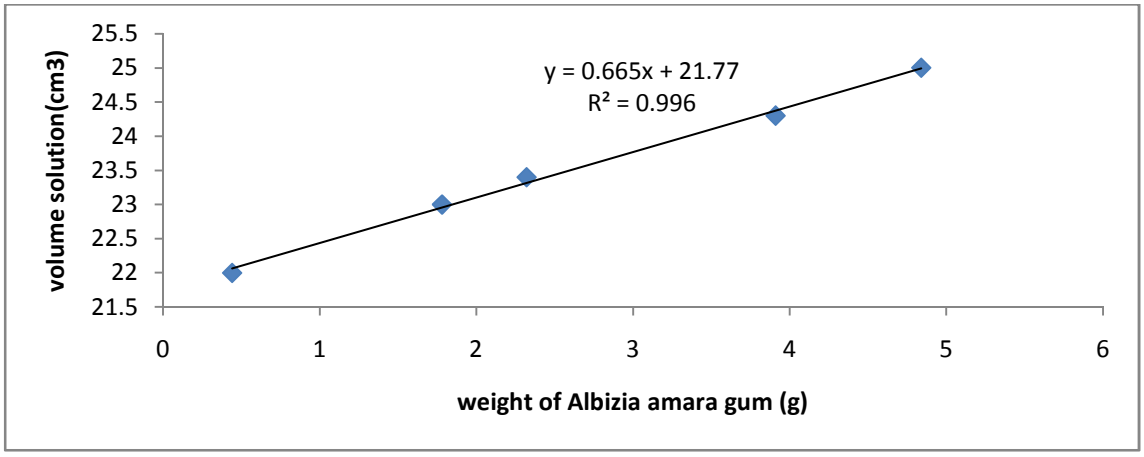
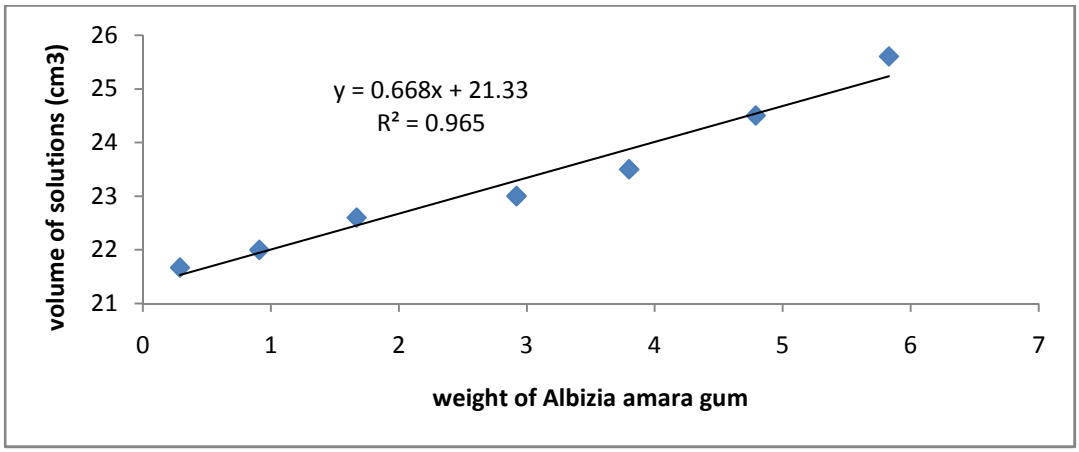


Figure (4.19) Partial specific volume in *Albizia amara* in *Albizia amara* gum solutionscomp2012.



Figure(4.20)Partial specific volume in *Albizia amara* in *Albizia amara* gum solutions comp2013.

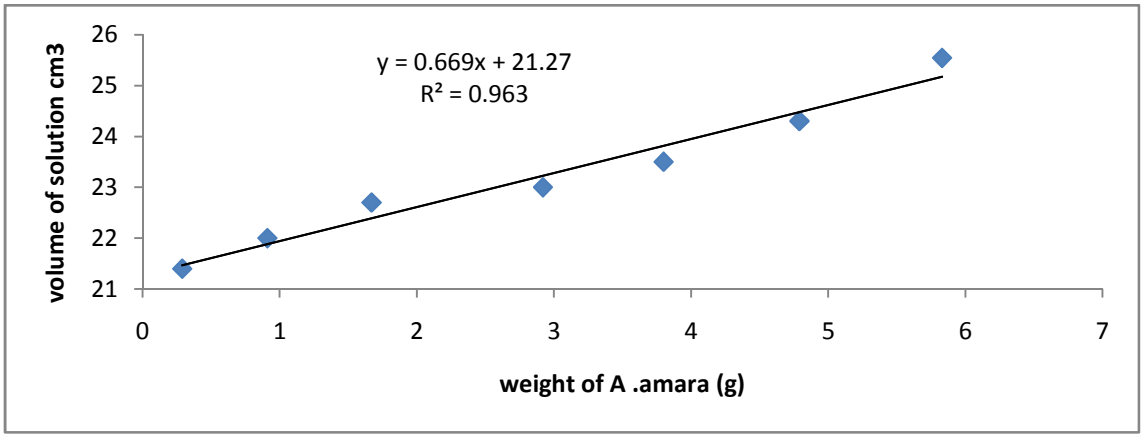


Figure (4.21) Partial specific volume of *Albizia amara* in *Albizia amara* gum solutions comp2014.

According to equation 2.18.3.10 section 2.18.3, it was possible to determine the chemical potential of water as a solvent in different gums solutions Tables 4.13, 4.14 and 4.15. The results show that the change in chemical potential of water in comp 2013 gum solutions was greater than that seen in comp 2012 gum solutions which are greater than the one recorded in comp 2014 gum solutions. There were no large differences between the results of the chemical potential of water in solution comp 2012, comp 2013, and comp 2014.

Table (4.13) Variation chemical potential of water ($\Delta \mu_1$) in *Albizia amara* gum solution in with concentration comp 2012.

Conc. g cm^{-3}	$\Delta\mu_1$ j g^{-1}
0.02	$-0.73377304 \times 10^{-3}$
0.04	$-0.880527648 \times 10^{-3}$
0.06	$-2.281367088 \times 10^{-3}$
0.08	$-3.89566776 \times 10^{-3}$
0.10	$-6.030280256 \times 10^{-3}$
0.12	$-7.497826336 \times 10^{-3}$
0.14	$-10.52935826 \times 10^{-3}$

Table (4.14) Variation chemical potential of water ($\Delta \mu_1$) in *Albizia amara* gum solution in concentration comp2013.

Conc. g cm^{-3}	$\Delta\mu_1$ j g^{-1}
0.03	$-0.1340816 \times 10^{-3}$
0.045	$-1.582526736 \times 10^{-3}$
0.06	$-2.6709312 \times 10^{-3}$
0.075	$-4.13994336 \times 10^{-3}$
0.09	$-4.6741296 \times 10^{-3}$
0.115	$-7.21151424 \times 10^{-3}$

Table (4.15) Variation chemical potential of water ($\Delta\ \mu_1$) in *Albizia amara* gum solution in concentration comp2014.

Conc. g cm^{-3}	$\Delta\mu_1$ j g^{-1}
0.01	-0.27269088 $x10^{-3}$
0.02	-0.54538176 $x10^{-3}$
0.03	-0.995321712 $x10^{-3}$
0.04	-1.717952544 $x10^{-3}$
0.05	-2.140623408 $x10^{-3}$
0.06	-2.788264248 $x10^{-3}$
0.07	-4.083545928 $x10^{-3}$

The chemical potential of *Albizia amara gum* comp 2012, comp 2013 and comp 2014 calculated by plotting ω_1 / ω_2 versus $\Delta\mu_1$ Figures 4.22,4.24 and 4.26 using result in Tables 4.16, 4.20 and 4.24. The areas under the curve ,that are bounded by ordinates corresponding to $\Delta\mu_2^{/}$ which less than the true areas values obtained of $\Delta\mu_2$ to correct areas , a graph , of dependence $\Delta\mu_2^{/}$ versus ω_1 was plotted to obtain Segment A Figures 4.23, 4.25 and 4.27. And obtained the true values of $\Delta\mu_2$ Table 4.17, 4.21and 4.25. The chemical potential of composite sample 2012, 2013 and 2014 was reported in Table 4.22 show that comp 2012, comp 2013 and comp 2014 are similar which also indication good solution in water .

Table (4.16) Data for plotting the chemical potential of water versus ω_1 / ω_2 of *Albizia amara* gum solution comp 2012

$\Delta\mu_1$ j g^{-1}	ω_1 / ω_2
-0.73377304x10^{-3}	49
-0.880527648 x10^{-3}	24
-2.281367088 x10^{-3}	15.67
-3.89566776 x10^{-3}	11.5
-6.030280256 x10^{-3}	9.0
-7.497826336 x10^{-3}	7.33
-10.52935826 x10^{-3}	6.143

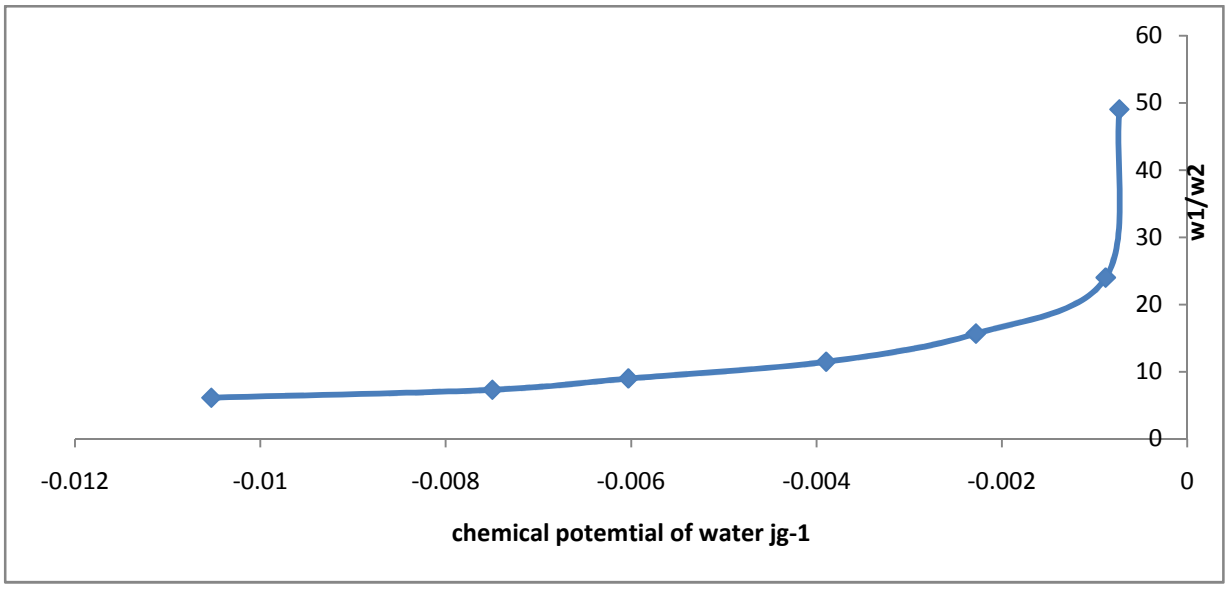


Figure (4.22) Chemical potential ($\Delta\mu_2^{/}$) of *Albizia amara* gum comp2012

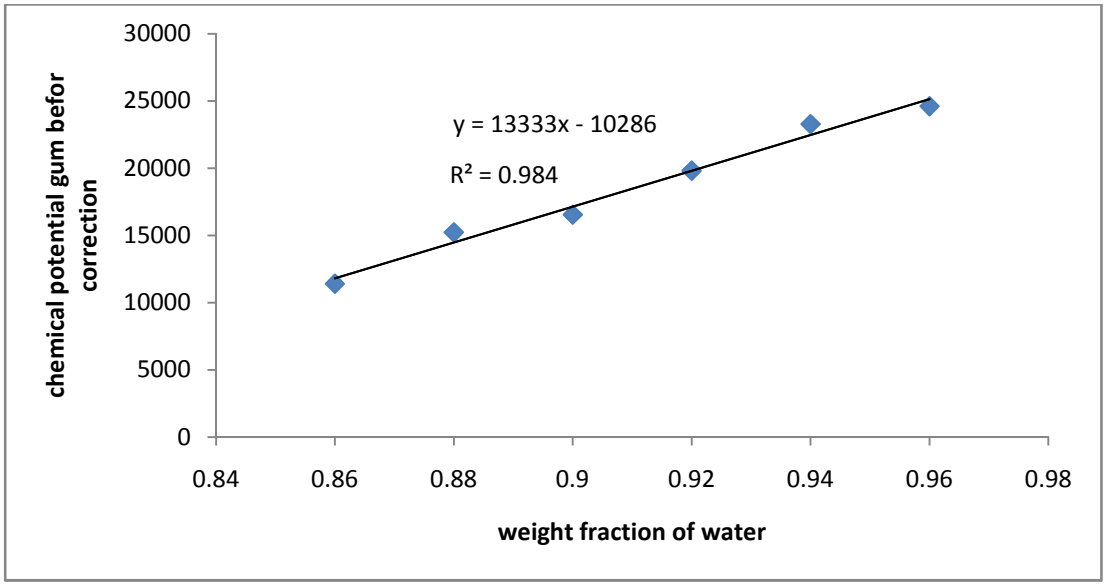


Figure (4.23) Segment A to correct the chemical potential of *Albizia amara* ($\Delta\mu_2$) in *Albizia amara* gum solution Comp2012

Table (4.17) Chemical potential of *Albizia amara* ($\Delta\mu_2$) in *Albizia amara* gum solution after correction comp2012

ω_1 / ω_2	$\Delta\mu_2$ / j g^{-1}	A	$\Delta\mu_2$j g^{-1}
7.33	1.1405 x10^{-3}	-10286	-2.1691x10^{-3}
9.00	1.5223 x10^{-3}	-10286	-2.5509 x10^{-3}
11.50	1.6533 x10^{-3}	-10286	-2.6819 x10^{-3}
15.67	1.9804 x10^{-3}	-10286	-3.0090 x10^{-3}
24.00	2.3263 x10^{-3}	-10286	-3.3549 x10^{-3}
49.00	2.4593 x10^{-3}	-10286	-3.4879 x10^{-3}

Table (4.18) Data for plotting the chemical potential of water versus ω_1 / ω_2 of *Albizia amara* gum solution comp 2013

$\Delta\mu_1$ j g^{-1}	ω_1 / ω_2
-0.1340816 $x10^{-3}$	32.33
-1.582526736 $x10^{-3}$	21.11
-2.6709312 $x10^{-3}$	15.67
-4.13994336 $x10^{-3}$	12.33
-4.6741296 $x10^{-3}$	10.11
-7.21151424 $x10^{-3}$	7.70

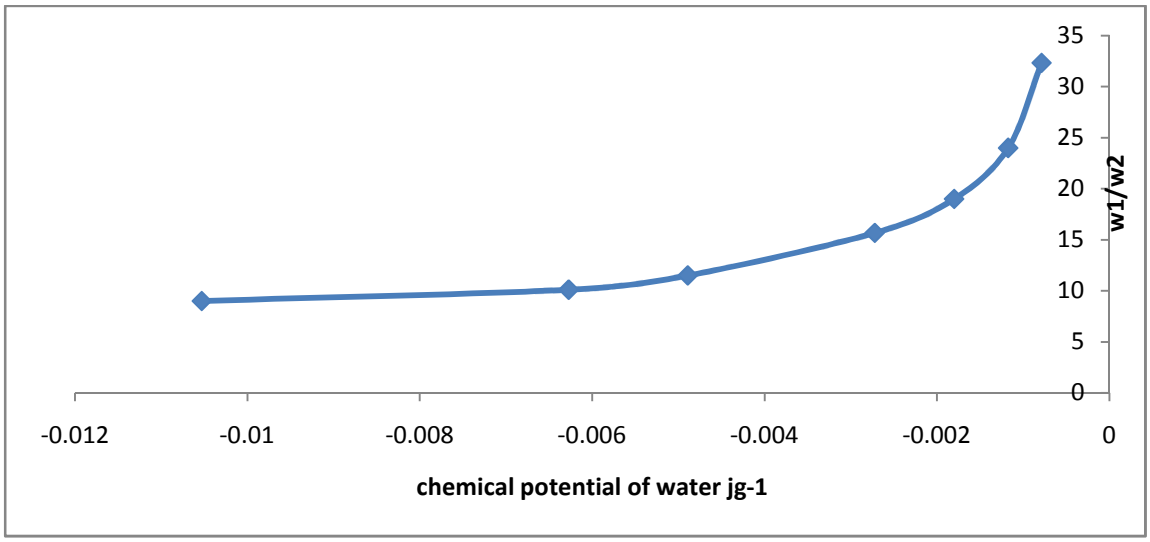


Figure (4.24) Chemical potential ($\Delta\mu_2{}^{/}$) of *Albizia amara* gum Comp2013

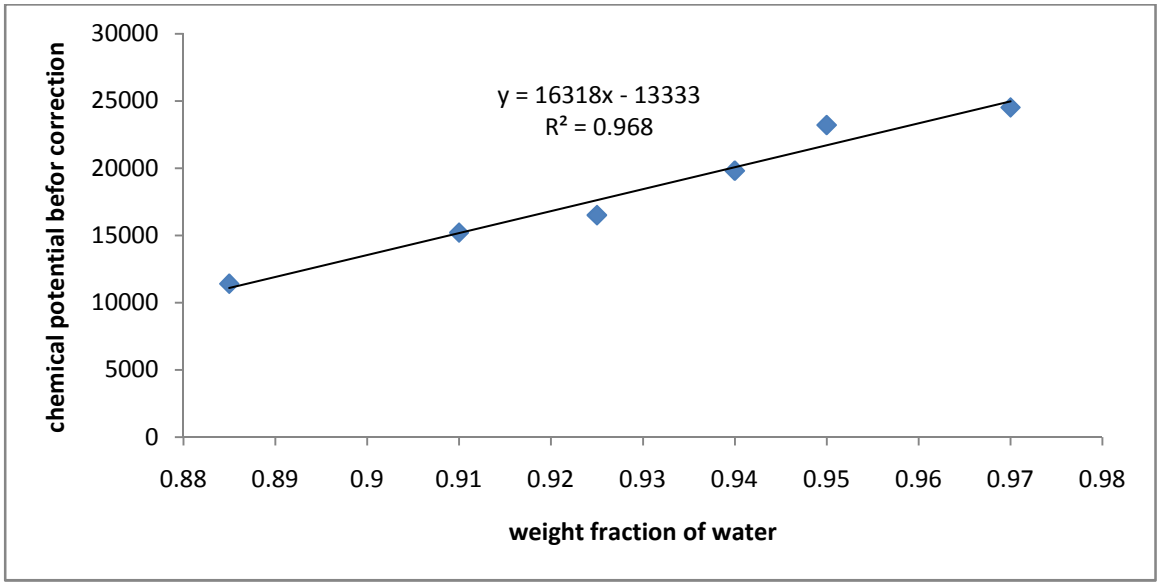


Figure (4.25) segment A to correct the chemical potential of *Albizia amara* ($\Delta\mu_2$) in *Albizia amara* gum solution comp2013.

Table (4.19) Chemical potential of *Albizia amara* ($\Delta\mu_2$) in *Albizia amara* gum solution after correction comp 2013

ω_1 / ω_2	$\Delta\mu_2 / jg^{-1}$	A	$\Delta\mu_2 j\ g^{-1}$
7.70	1.1400×10^{-3}	-13333	-2.4733×10^{-3}
10.70	1.5200×10^{-3}	-13333	-2.8533×10^{-3}
12.33	16500×10^{-3}	-13333	-2.9833×10^{-3}
15.67	1.9800×10^{-3}	-13333	-3.3133×10^{-3}
21.11	2.3200×10^{-3}	-13333	-3.6533×10^{-3}
32.33	2.4500×10^{-3}	-13333	-3.7833×10^{-3}

Table (4.20) Data for plotting the chemical potential of water versus ω_1 / ω_2 of *Albizia amara* gum solution comp 2014

$\Delta\mu_1$ j g^{-1}	ω_1 / ω_2
-0.27269088 x10^{-3}	99
-0.54538176 x10^{-3}	49
-0.995321712 x10^{-3}	32.33
-1.717952544 x10^{-3}	24
-2.140623408 x10^{-3}	19
-2.788264248 x10^{-3}	15.67
-4.083545928 x10^{-3}	11.5

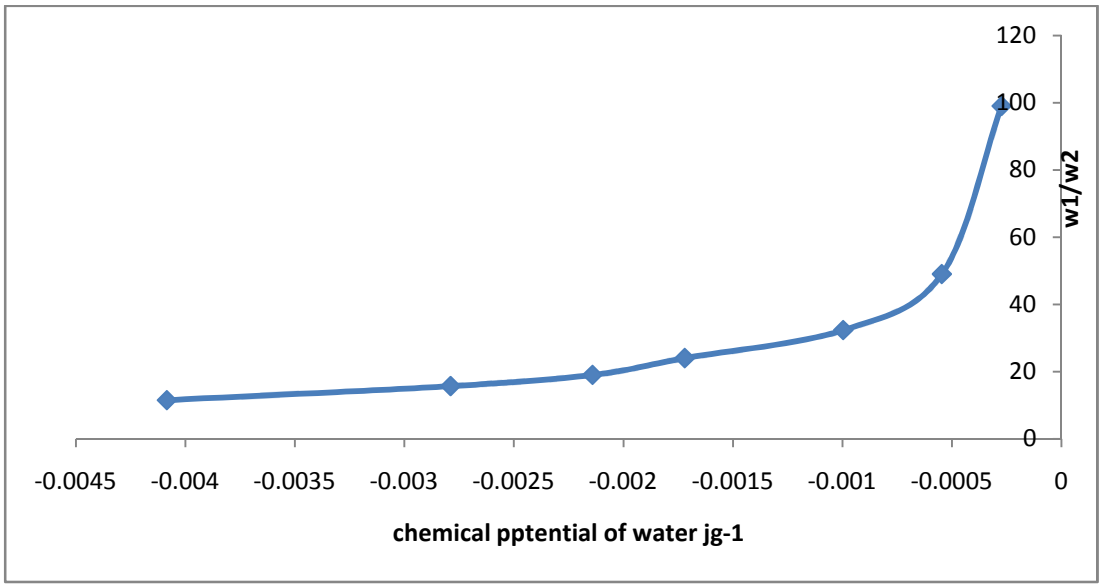


Figure (4.26) Chemical potential ($\Delta\mu_2^{/}$) of *Albizia amara* gum Comp2014

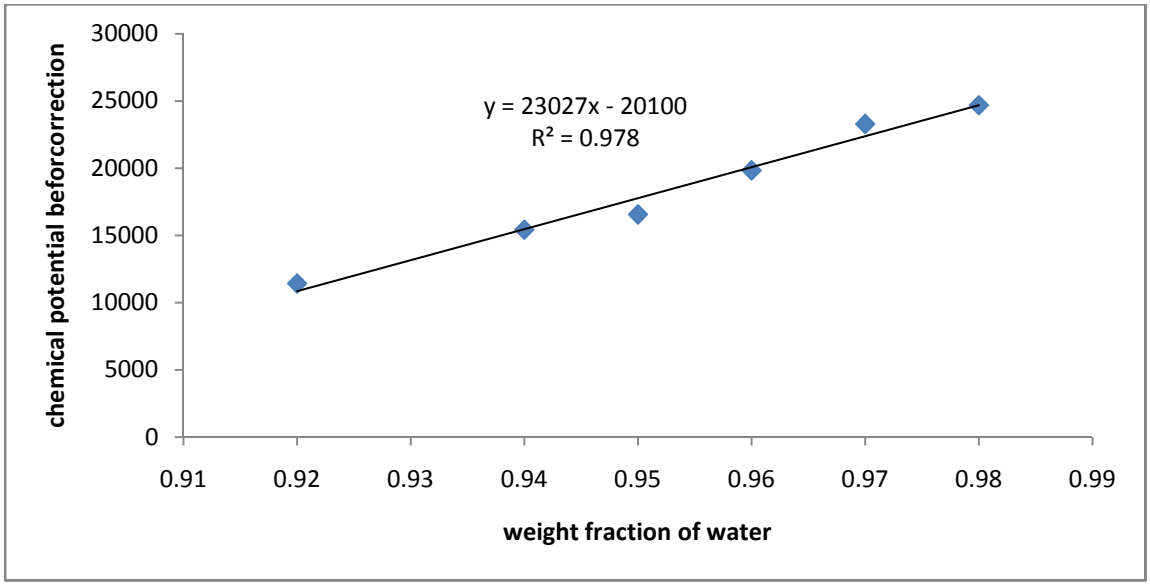


Figure (4.27) segment A to correct the chemical potential of *Albizia amara* ($\Delta\mu_2$) in *Albizia amara* gum solution 2014.

Table (4.21) Chemical potential of *Albizia amara* ($\Delta\mu_2$) in *Albizia amara* gum solution after correction comp2014

ω_1 / ω_2	$\Delta\mu_2^{/}$ jg^{-1}	A	$\Delta\mu_2$j g^{-1}
11.5	1.1415 x10^{-3}	-20100	-3.1515 x10^{-3}
15.5	1.5413 x10^{-3}	-20100	-3.5513 x10^{-3}
19	1.6551 x10^{-3}	-20100	-3.6651 x10^{-3}
24	1.9832 x10^{-3}	-20100	-3.9932 x10^{-3}
32.33	2.3287 x10^{-3}	-20100	-4.3387 x10^{-3}
49	2.4681 x10^{-3}	-20100	-4.4781 x10^{-3}

Table (4.22) Chemical potential of *Albizia amara* ($\Delta\mu_2$) in *Albizia amara* gum solution after correction.

$\Delta\mu_2$ j g^{-1}		
Comp 2012	Comp 2013	Comp 2014
-2.1691×10^{-3}	-2.4733×10^{-3}	-3.1515×10^{-3}
-2.5509×10^{-3}	-2.8533×10^{-3}	-3.5513×10^{-3}
-2.6819×10^{-3}	-2.9833×10^{-3}	-3.6651×10^{-3}
-3.0090×10^{-3}	-3.3133×10^{-3}	-3.9932×10^{-3}
-3.3549×10^{-3}	-3.6533×10^{-3}	-4.3387×10^{-3}
-3.4879×10^{-3}	-3.7833×10^{-3}	-4.4781×10^{-3}

Free energy of mixing of *Albiziza amara* gum comp 2002, comp 2013 and comp 2014 by using equation 2.18.10.5 was reported in Tables 4.23, 4.24, and 4.25. From the results it was observed that comp 2013 gum has high values of free energy and this indicate that it interacts with water more than the other two gum samples and comp 2012 gum intercts with water more than comp 2014gum.Table 4.26 show that *Albiziza* amara gum, comp 2012, comp 2013 and comp 2014 have closed values and have larger values of osmotic pressure, greater change in chemical potential and free energy of mixing of the entire system.

Table (4.23) Calculating the free energy of mixing of *Albizia amara* solution comp 2012.

$\Delta\mu_1$ j g^{-1}	ω_1	$\Delta\mu_1 x\, \omega_1$	$\Delta\mu_2$j g^{-1}	ω_2	$\Delta\mu_2 x\, \omega_2$	$\Delta G^m = \Delta\mu_1 x\, \omega_1 + \Delta\mu_2 x\, \omega_2$ jg^{-1}
$-0.73377304 \times 10^{-3}$	0.96	$-.070442 \times 10^{-3}$	-2.1691×10^{-3}	0.04	-0.08676×10^{-3}	-0.79118×10^{-3}
$-0.880527648 \times 10^{-3}$	0.94	-0.82769×10^{-3}	-2.5509×10^{-3}	0.06	-0.15305×10^{-3}	-0.98074×10^{-3}
$-2.281367088 \times 10^{-3}$	0.92	-2.09885×10^{-3}	-2.6819×10^{-3}	0.08	-0.21455×10^{-3}	-2.3134×10^{-3}
$-3.89566776 \times 10^{-3}$	0.90	-3.50609×10^{-3}	-3.0090×10^{-3}	0.10	-0.3009×10^{-3}	-3.80699×10^{-3}
$-6.030280256 \times 10^{-3}$	0.88	-5.30665×10^{-3}	-3.3549×10^{-3}	0.12	-0.40259×10^{-3}	-5.70924×10^{-3}
$-7.497826336 \times 10^{-3}$	0.86	-6.44813×10^{-3}	-3.4879×10^{-3}	0.14	-0.48831×10^{-3}	-6.93644×10^{-3}

Table (4.24) Calculating the free energy of mixing of *Albizia amara* solution comp 2013.

$\Delta\mu_1$ j g^{-1}	ω_1	$\Delta\mu_1 x\, \omega_1$	$\Delta\mu_2$ j g^{-1}	ω_2	$\Delta\mu_2 x\, \omega_2$	$\Delta G^m = \Delta\mu_1 x\, \omega_1 + \Delta\mu_2 x\, \omega_2$ j g^{-1}
$-0.1340816 \times 10^{-3}$	0.97	-0.13006×10^{-3}	-2.4733×10^{-3}	0.03	-0.0742×10^{-3}	-0.20426×10^{-3}
$-1.582526736 \times 10^{-3}$	0.95	-1.50343×10^{-3}	-2.8533×10^{-3}	0.05	-0.14267×10^{-3}	-1.6461×10^{-3}
$-2.6709312 \times 10^{-3}$	0.94	-2.51073×10^{-3}	-2.9833×10^{-3}	0.06	-0.179×10^{-3}	-2.6963×10^{-3}
$-4.13994336 \times 10^{-3}$	0.925	-3.82944×10^{-3}	-3.3133×10^{-3}	0.075	-0.248497×10^{-3}	-4.15823×10^{-3}
$-4.6741296 \times 10^{-3}$	0.91	-4.25345×10^{-3}	-3.6533×10^{-3}	0.09	-0.328797×10^{-3}	-4.58219×10^{-3}
$-7.21151424 \times 10^{-3}$	0.885	-6.38219×10^{-3}	-3.7833×10^{-3}	0.115	-0.43508×10^{-3}	-6.81718×10^{-3}

Table (4.25) Calculating the free energy of mixing of *Albizia amara* solution comp 2014.

$\Delta\mu_1$ j g^{-1}	ω_1	$\Delta\mu_1 x\, \omega_1$	$\Delta\mu_2$j g^{-1}	ω_2	$\Delta\mu_2 x\, \omega_2$	$\Delta G^m = \Delta\mu_1 x\, \omega_1 + \Delta\mu_2 x\, \omega_2$ j g^{-1}
$-0.54538176 \times 10^{-3}$	.098	-0.53447×10^{-3}	-3.1515×10^{-3}	0.02	-0.06303×10^{-3}	-0.5975×10^{-3}
$-0.995321712 \times 10^{-3}$	0.97	-0.96546×10^{-3}	-3.5513×10^{-3}	0.03	-0.10654×10^{-3}	-1.072×10^{-3}
$-1.717952544 \times 10^{-3}$	0.96	-1.64923×10^{-3}	-3.6651×10^{-3}	0.04	-0.1466×10^{-3}	-1.79583×10^{-3}
$-2.140623408 \times 10^{-3}$	0.95	-2.03359×10^{-3}	-3.9932×10^{-3}	0.05	-0.19966×10^{-3}	-2.23325×10^{-3}
$-2.788264248 \times 10^{-3}$	0.94	-2.62096×10^{-3}	-4.3387×10^{-3}	0.06	-0.26032×10^{-3}	-2.88128×10^{-3}
$-4.083545928 \times 10^{-3}$	0.92	-3.75686×10^{-3}	-4.4781×10^{-3}	0.08	-0.35825×10^{-3}	-4.83635×10^{-3}

Table (4.26) Free energy of mixing of *Albizia amara*, with water in (j g^{-1})

$\Delta G^m 2$ j g^{-1}		
Comp 2012	Comp 2013	Comp 2014
-0.79118 x10^{-3}	-0.20426 x10^{-3}	-0.5975 x10^{-3}
-0.98074 x10^{-3}	-1.6461 x10^{-3}	-1.072 x10^{-3}
-2.3134 x10^{-3}	-2.6963 x10^{-3}	-1.79583 x10^{-3}
-3.80699 x10^{-3}	-4.15823 x10^{-3}	-2.23325 x10^{-3}
-5.70924 x10^{-3}	-4.58219 x10^{-3}	-2.88128 x10^{-3}
-6.93644 x10^{-3}	-6.81718 x10^{-3}	-4.83635 x10^{-3}

Summary, conclusion and suggestions for further work

Summary and Conclusion

-The physicochemical properties of sample tested are similar with those previously reported studies on gum plant from the *vulgare*s series that contain *A. Senegal A. leata, . A.polycantha,* and *A.melliera* ..etc.

- The gum from the *Albizia amara* has a negative optical rotation Similar to *Acacia vulgares* series.

- The gum from the *Albizia amara* is a good emulsifier

-The gum from *Albizia amara* has good Antioxidant capacity

- Thermodynamic parameters of the gum from *Albizia amara* fall within the range of the *vulgares* species. However, those of *A .polycantha* from the *A.Senegal* complex also show close similarity .

Suggestions for further work

1- To Study amino acid composition of the *Albiziza amara* gum and determine NC factor of protein.

2- To Study the toxicity of the *Albizia amara* gum.

3- To study the rheological behavior properties of *Albizia amara* gum

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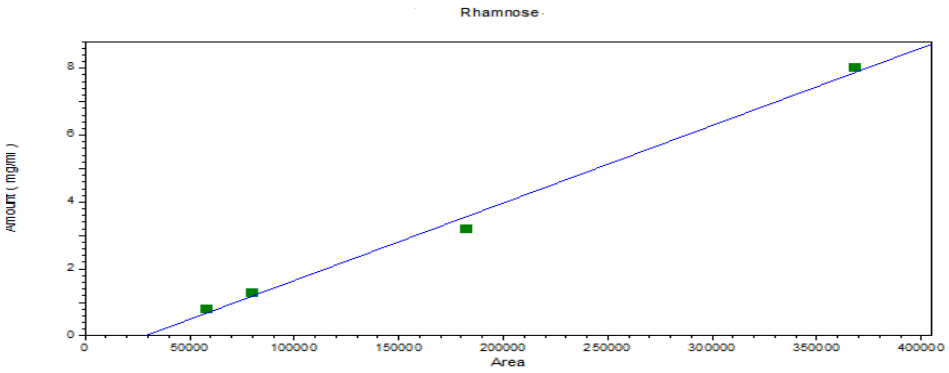
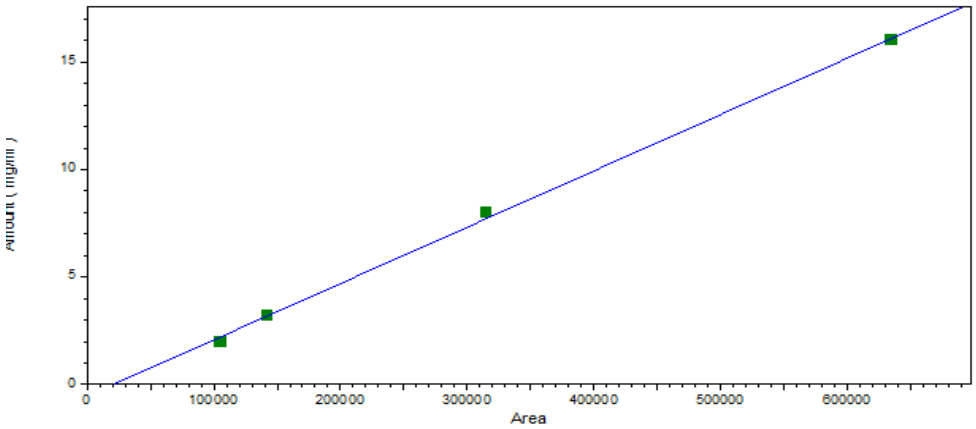
Appendices

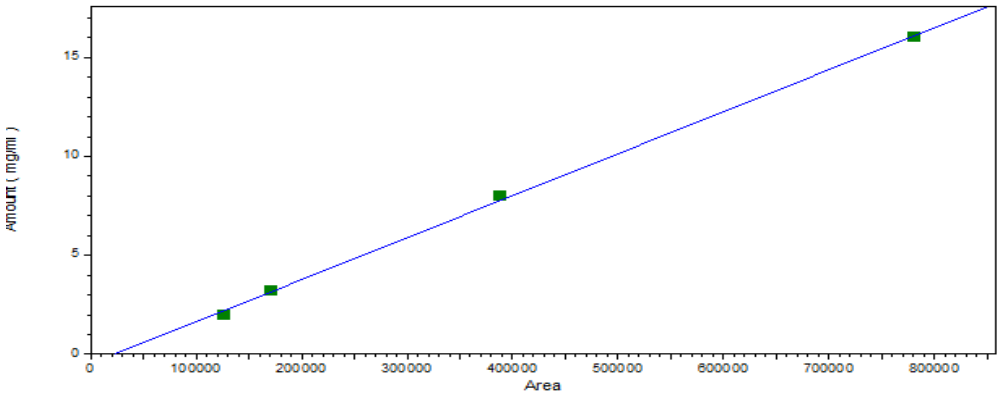
Appendix1. 1. Calibration curve of rhmanose



Appendix1.2. Calibration curve of arabinose



Appendix 1. 3. Calibration curve of galactose



Appendix (2.1) Partial specific volume of water in *Albizia amara* gum solutions comp2012

Gum concentration w/w%	Weight of gum w2(g)	Weight of water w1(g)	Solution volume (cm^3)
2%	2	97.1082	98.7133
4%	2	47.5632	49.3657
6%	2	31.0482	32.9165
8%	2	22.7907	24.6919
10%	2	17.4362	18.4571
12%	2	14.5331	16.4672
14%	2	12.1739	14.1174
16%	2	10.4045	12.3550

Appendix (2.2) Partial specific volume of *Albizia amara* in *Albizia amara* gum solutions comp2013

Gum concentration w/w%	Weight of gum w2(g)	Weight of water w1(g)	Solution volume(cm^3)
1.4%	0.291	20.8306	20.9401
2.4%	0.5001	20.8306	21.5366
4.4%	0.9165	20.8306	21.5492
6.4%	1.3331	20.8306	21.9620
8%	1.6664	20.8306	22.2922
10%	2.0831	20.8306	22.7051
14%	2.9163	20.8306	23.5308
18%	3.7495	20.8306	24.3564
23%	4.7910	20.8306	25.3884
28%	5.8326	20.8306	26.4205

Appendix (2.3) Partial specific volume of water in *Albizia amara* gum solutionscomp2014

Gum concentration w/w%	Weight of gum w2(g)	Weight of water w1(g)	Solution volume (cm^3)
2%	2	97.102	98.7033
4%	2	47.5632	49.3767
6%	2	31.0482	32.9144
8%	2	22.7907	24.6811
10%	2	17.4362	18.4570
12%	2	14.5331	16.4760
14%	2	12.1739	14.2013
16%	2	10.4045	12.3459

Appendix (3.1) Partial specific volume of *Albizia amara* in *Albizia amara* gum solutions comp2012

Gum concentration w/w%	Weight of gum w2(g)	Weight of water w1(g)	Solution volume(cm^3)
1.4%	0.2860	20.8306	21.3105
2.4%	0.5221	20.8306	21.5487
4.4%	0.9234	20.8306	21.95378
6.4%	1.2231	20.8306	22.2629
8%	1.6745	20.8306	22.7127
10%	2.0741	20.8306	23.1150
14%	2.9052	20.8306	23.9538
18%	3.8011	20.8306	24.8579
23%	4.6823	20.8306	25.7471
28%	5.8037	20.8306	26.8789

Appendix (3.2) Partial specific volume of water in *Albizia amara* gum solutionscomp2013

Gum concentration w/w%	Weight of gum w2(g)	Weight of water w1(g)	Solution volume (cm^3)
2%	2	97.122	98.7211
4%	2	47.6534	49.3687
6%	2	31.1234	32.9201
8%	2	22.8790	24.6719
10%	2	17.3353	18.4059
12%	2	14.6.547	16.4590
14%	2	12.1737	14.1213
16%	2	10.54412	12.3601

Appendix (3.3) Partial specific volume of *Albizia amara* in *Albizia amara* gum solutions comp2014

Gum concentration w/w%	Weight of gum w2(g)	Weight of water w1(g)	Solution volume(cm^3)
2.4%	0.4432	20.8306	21.4691
4.5%	1.0123	20.8306	22.0435
6.5%	1.5341	20.8306	22.5700
8.3%	1.7841	20.8306	22.8223
10.3%	2.1918	20.8306	23.2338
14.3%	2.3234	20.8306	23.3666
18.3%	3.9145	20.8306	24.9723
23.3%	4.8425	20.8306	25.9089

Appendix (4.1) Osmotic pressure of *Albizia amara* of different concentration

π mmHg		
Comp2012	Comp2013	Com104
5.5	8	2
6.6	11.85	4
17.1	20	7.3
29.2	31	12.6
45.2	35	15.7
56.2	54	20.45

Appendix (5.1) Data for plotting the chemical potential before correction Versus weight fraction of water of *.Albizia amara* solution

$\Delta\mu_2$ jg^{-1}	ω_1
$1.1405x10^{-3}$	0.86
$1.5223\ x10^{-3}$	0.88
$1.6533\ x10^{-3}$	0.90
$1.98046\ x10^{-3}$	0.92
$2.3263\ x10^{-3}$	0.94
$2.4593\ x10^{-3}$	0.96

Appendix (5.2) Data for plotting the chemical potential before correction Versus weight fraction of water of *.Albizia amara* solution comp2013

$\Delta\mu_2^{/}$ jg^{-1}	ω_1
1.1400 x10^{-3}	0.885
1.5200 x10^{-3}	0.91
1.6500 x10^{-3}	0.925
1.9800 x10^{-3}	0.94
2.3200 x10^{-3}	0.95
2.4500 x10^{-3}	0.97

Table (5.3) Data for plotting the chemical potential before correction Versus weight fraction of water of *.Albizia amara* solution comp2014

$\Delta\mu_2^{/}$jg^{-1}	ω_1
1.1415x10^{-3}	0.92
1.5413 x10^{-3}	0.94
1.6551 x10^{-3}	0.95
1.9832 x10^{-3}	0.96
2.3287 x10^{-3}	0.97
2.4681 x10^{-3}	0.98

Appendix 6.1 Tree of *Albizia amara*

Appendix 6.1 Fruit of *Albizia amara*

Appendix 6.1 Seed of *Albizia amara*