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Impact of Heat Treatment on Spray Dried Gum Arabic Powder and its Effects on Physico-chemical Properties of its Solution and its Emulsion

أثر المعالجة الحرارية لبدرة الصمغ العربي المجفف رزازياً وتأثيرها على الخواص الفيزيوكيميائية لمحلوله ومستحلباته

A Dissertation Submitted in Partial Fulfillment of the Requirement for the Master Degree of Science in Chemistry

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الاستهلال

بسم الله الرحمن الرحيم

اللَّهُ لَا إِلَٰهَ إِلَّا هُوَ الْحَيُّ الْقَيُّومُ لَا تَأْخُذُهُ سِنَةٌ وَلَا نَوْمٌ لَّهُ مَا فِي السَّمَاوَاتِ وَمَا فِي الْأَرْضِ مَن ذَا الَّذِي يَشْفَعُ عِندَهُ إِلَّا بِإِذْنِهِ يَعْلَمُ مَا بَيْنَ أَيْدِيهِمْ وَمَا خَلْفَهُمْ وَلَا يُحِيطُونَ بِشَيْءٍ مِّنْ عِلْمِهِ إِلَّا بِمَا شَاءَ وَسِعَ كُرْسِيُّهُ السَّمَاوَاتِ وَالْأَرْضَ وَلَا يَئُودُهُ حِفْظُهُمَا وَهُوَ الْعَلِيُّ الْعَظِيمُ

سورة البقرة الايه ٢٥٥

Dedication

To my parents .

Acknowledgement

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Abstract

The objective of this study is to investigate the effect of heat treatment on raw *Acacia* gums and its implications on the physico-chemical prosperities on gum solution viscosity and the stability of their emulsion. Sample of *Acacia* gums namely *Acacia senegal* var *senegal* and *Acacia seyal* var *seyal* , were heated at 150°C for different time intervals (17, 48 and 72 hours) in an oven. The physic- chemical prosperities of the heat- treated gum samples were examined where the ash content, pH, specific optical rotation and viscosity of their solution were obtained, following AOAC standard methods.The results revealed that ash content average for *Acacia senegal* and *Acacia seyal* 2.5 and 2.1 respectively and pH of its between 4.4 to 4.6 .the samples subjected to heat treatment remained unaltered compared to the control sample .The specific optical rotation and viscosity of solution of heat treated samples showed very significant changes. The optical rotation for all samples differs in their value ,the value in *Acacia senegal* heat treated for17.48and72 hours equal -26.77,-12.50 and -10.00(degreeml$g^{-1}dm^{-1}$) respectively , the Optical rotation value in *Acacia seyal* heat treated for17.48and72 hours equal -+317.5,+239 and +314.5(degreeml$g^{-1}dm^{-1}$) respectively. but not in the direction of rotation. The increase in solution viscosity was noticeably high for samples of *Acacia senegal* heated for 48 hours viscosity reach 4731%compared to the control in the value and its order of magnitude. The emulsifying index for the control and heat-treated samples follow the well establish stability characteristics of the two types of gum, where *Acacia senegal* shows high stability compared to *Acacia seyal*. The heat treatment for 72hours had improved the stability of *Acacia senegal* gum slightly compared to the control sample. While heat treatment for 17 hours improved the stability of *Acacia seyal* gum in comparison to the control sample.

المستخلص

هدفت هذه الدراسة للتحقق من تأثير المعالجة الحرارية لصمغ الاكاسيا الخام وتأثيرذلك علي الخواص الفيزيوكيميائية وثباتية محاليل ومستحلبات تلك الاصماغ. تم تسخين عينات من أصماغ الاكاسيا الي ١٥٠° درجة مئوية لفترات زمنية مختلفة(٤٨,١٧ ,٧٢) في فرن. تم اختبار الخصائص الفيزيوكيميائية لمحاليل العينات المعالجة حراريا حيث تم قياس محتوي الرماد والاس الهيدروجيني والدوران الضوئي النوعي ولزوجة المحاليل. تم اتباع طرق اتحاد الكيميائين الزراعيين في التحليل وبينت النتائج ان متوسط محتوي الرماد لصمغ الاكاسيا سينقال والاكاسيا سيال ٢,٥و٢,١ على التوالي و الاس الهيدروجيني للعينات المعالجة حراريا ٤,٤الي٤,٦وانها لم تتغير مقارنا بعينة التحكم. ولكن الدوران الضوئي النوعي ولزوجة محاليل العينات المعالجة حراريا اظهرت تغيراً ملحوظاً.اختلفت قيم الدوران الضوئي النوعي لكل العينات وصلت قيم الدوران الضوئي لعينات الاكاسيا سينقال المعالجة حراريا لفترات مختلفة(٤٨,١٧ ,٧٢) الى- ٢٦,٧٧، -١٢,٥و-١٠ على التوالي وصلت قيم الدوران الضوئي لعينات الاكاسيا سيال المعالجة حراريا لفترات مختلفة(٤٨,١٧ ,٧٢) الى+٣١٧,٥ ، + ٢٣٩و+٣١٤,٥، على التوالي ولكن لم يتأثر اتجاة الدوران. أظهرت النتائج أن الزيادة في اللزوجه لعينه الاكاسيا سينقال المعالجه حرارياً لفترة ٤٨ساعة كانت عاليه في المعدل تصل الى ٤٧٣١% مقارنة بعينة التحكم في النسبة و في المقدار.توافقت العينات المعالجه حرارياً فيما يتعلق بمعامل الاستحلاب مع الخصائص العامه المتعارف عليها لهذه الاصماغ كما في الدراسات المنشورة. حيث اظهرت عينة صمغ الهشاب ثباتية عالية مقارنة بصمغ الطلحه.وقد حسنت المعالجة الحرارية لمدة ٧٢ ساعة من ثباتيه مستحلب صمغ الهشاب بصورة طفيفة مقارنة بعينة التحكم بينماحسنت المعالجة الحرارية لمدة ١٧ ساعة من ثبات مستحلب عينات صمغ الطلحة مقارنة بعينة التحكم

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List of Abbreviations

AOAC	Association of Agricultural Chemist
GA	Gum Arabic
UV	Ultra violet
GP	Glyco protein
AGP	Arabinogalactan protein
GSH	Glutathione
AA	Ascorbic acid
SOD	Super oxide dismutase
O\W	Oil in water
W\O	Water in oil
FTIR	Fourier transform infrared
ICH	International council for harmonization
MW	Molecular weight
SI	Stability index

Chapter One

Introduction

1. Introduction

Gum Arabic refers to dried exudates obtained from the stems and branches of *Acacia senegal* or *Acacia seyal.* However, the quantity and quality produced varies between and among species and this determine the type and extent of use by man. Most studies show that the main countries producing commercial *Acacia* gums are in Sub-Saharan Africa. Most of these Gums are edible and some are used in the food and pharmaceutical industries(Williams.*et al*., 2000).

The gum from *Acacia senegal* is a water soluble poly saccharide of the hydrocolloid group and comprised mostly of Arabino galactan and Protein moiety, in addition to some mineral elements.(Abd-Allah.*et al*.,2012).

Many of these gums have considerable variation in physicochemical, functional and toxicological properties according to different locations, type of soil and age of the tree.(Anderson .*et al*.,1968).

An emulsion consists of a dispersion of a liquid as small droplets (with size ranging from several μm to nm) in another immiscible liquid. Emulsions are present in numerous industrial applications such as food products (milk, butter, mayonnaise or flavored beverages), cosmetic or pharmaceutical products (moisturizing creams, encapsulating active ingredients), and bitumen for road coatings or in the paint industry.(Toulouse and Atgie., 2018)

Gum Arabic is known by the world wide food, beverage and pharmaceutical industry as a versatile additive with polyvalent functions: Protective colloid, film-building and coating agent, encapsulating agent, oxidation inhibitor, stabilizer, emulsifier, texturing, clouding and clarifying agent and food adhesive. More recently, western countries discovered that *Acacia* gum is also a dietary fiber with very interesting nutritional properties.(Ngara.,2005).

Such systems are widely used because they combine benefits of both phases. For instance, in a moisturizing cream the aqueous phase brings a fresh sensation while the oil phase contributes to the deposition of a protective film at the skin surface(Toulouse and Atgie., 2018).

Several types of emulsion exist: direct emulsions (oil-in-water), inverse emulsions (water-in-oil) or multiple emulsions (water-in-oil in water for instance). Emulsions are thermo dynamically unstable systems. Without the presence of interfacial agents, emulsions break to yield two separate phases. Several types of interfacial agents exist and are used for the stabilization of dispersed systems such as emulsions. A formulation may contain surfactants, nano particles, proteins, micro-gels, block-copolymers. All these species are able to adsorb at oil/water interface and to protect droplets against coalescence. The demand for natural additives in formulation is steadily increasing, regarding environmental and health issues.(Toulouse and Atgie., 2018)

Gum refers to any polysaccharide that is dispersible in water to give viscous solution, gels or colloidal dispersions. Generally gums are long chain high molecular weight polymers that dissolve or disperse in water to give thickening or gelling effect and exhibit related secondary functional properties, such as emulsification, stabilization, and encapsulation .Gums, or hydrocolloids, are mainly long – chain, straight to branched polysaccharides that contain hydroxyl groups that can bond to water molecules.(Omer *et al.*, 2015)

Hydrocolloids constitute a class of natural products such as proteins or poly saccharides, which sometimes possess emulsifying and stabilizing properties. Among these, gum Arabic, an *Acacia* tree exudates, has been used for millennia due to its outstanding interfacial properties. This natural product is a complex mixture of biopolymers. Many attempts have been carried out, with limited success, to mimic interfacial properties of this product. A deeper understanding of the structure and composition of gum Arabic but also of its behavior at oil/water interfaces and of the stabilization mechanisms involved is thus required.(Toulouse and Atgie, 2018)

Many food products in the markets are in the emulsion state such as cheese, milk, salad dressings, sauces, beverages and coconut milk .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 .The emulsions are thermo dynamically unstable systems and have a tendency to break down over time .The breakdown of an emulsion may manifest itself through different physicochemical mechanisms such as gravitational separation, coalescence, flocculation, Ostwald ripening and phase inversion .Therefore, the production of high quality food emulsions that can remain kinetically stable for a certain period of time is necessary. In general, emulsifiers are needed for stabilizing emulsions because they decrease the interfacial tension between the oil and water phases and form a protective coating around the droplets which prevents them from coalescing with each other. (Sabah *et al.*, 2008)

The sugar monomers can contain linked side units, or substituent groups, such as sulphates, methyl ethers, esters and acetals. Gums composed mainly of C, H, O and N elements, and the acidic gums (e.g. Gum Arabic) contain mainly Ca, Mg, Na, and Fe, as cations.

Emulsions are chemical mixtures of liquids that are immiscible under ordinary conditions, and which may be separated into two layers on, standing, heating, and freezing, by agitation or the addition of other chemical. The emulsifying agents act as surface-active agents, which when added to an emulsion it would increase its stability by interfacial action. Each emulsifying agent depends on its action on different principle to achieve stable product. Gum Arabic is used to stabilize flavor oil emulsions in the dried food mixes (such as soup, cakes … etc.) and in the soft drinks industry, where the gum is required to stabilize concentrated oil emulsion (about20%) for long periods and also to continue to stabilize following dilution prior to bottling. Emulsifying agent is usually along – chain organic compound that has protruding chains that are soluble in oil (lysophilic) as well as side chains or groups that are soluble in water (hydrophilic). Thus one portion of each molecule dissolve in the water phase while another portion dissolves in the oil phase and the main chain forms a link or bridge

to keep both phases in position and there by emulsified. Gum Arabic produces highly stable emulsions making it very useful in the preparation of oil in water food flavor emulsions particularly for citrus oils. Some believe that gums are not true emulsifiers.(Omer *et al.*, 2015)

The main area of the Gum Arabic occurrences is the central parts of the Sudan, where a continuous belt extended east to west .In the western sand plains of Kordofan and Darfur the *Acacia senegal* var *senegal* species is found in uniform pure stands, giving the Sudan the advantages of being the biggest producer and exporter of best qualities. *Acacia senegal* trees are now planted each year in selected areas of the Sudan to stabilize soil erosion, nitrogen fixation, therefore gum Arabic production is important ecologically and economically.

The solubility and viscosity of the gum are the most fundamental properties, which make it unique amongst polysaccharides, the majority of gums dissolve in water at different concentrations, and such properties of gums are exploited in many applications. Gum Arabic is extensively used in the confectionary industry because it has ability to prevent crystallization of sugar and also because of its thickening effect. It is used to act as a glaze in candy products and as a component of chewing gum, cough drops and candy lozenges. Gum Arabic is used in frozen products, such as ice creams, ices and sherbets as stabilizer. Gums by their high viscosity in solutions and inability to crystallize, are particularly suited to serve in food stuff as: thickeners for beverages, stabilizers for oil and water emulsions and as wider application where function is to prevent agglomeration and setting out of minute particles. Due to the high water holding properties of the gum; the gum imparts a smooth texture to the frozen product by inhibiting the formation of ice crystals.(Omer *et al.*, 2015).

The gum is used as flavor fixative, forms a thin and impenetrable film around the flavor particle protecting it from oxidation, evaporation and absorbing moisture. Gum is used as a thickening agent for pigment in printing fabrics**.** It prevent dyestuff in pad dying operations, and produces very fine line prints with good definition and excellent washout .(Omer *et al.*, 2015).

1.1 Gum Arabic Sources and Processing

Acacia senegal and *Acacia seyal* trees are the main sources of Gum Arabia (GA). These species naturally grow in the semi-arid sub-Saharan regions of Africa. There are over 1000 species of *Acacia* and a summary of their botanical classification was reported. Sudan has traditionally been the main GA producer and its derivatives until the early 60s with a production of 60 kTn/year. Nevertheless, such a production decreased from60 kTn/year to 20 kTn/year in the '70s and '80s due to extensive drought and unstable governments. These facts prompted new GA-producing countries such as Chad and Nigeria which produce mainly *Acacia seyal.(*Abdel nour ,.1999).

Europe and U.S. are the most important GA markets importing 40 kTn/year,on average, while Japan, the largest Asian consumer, imports about 2 kTn/year.(Abdel nour ,.1999).

The crude exudates of GA is processed differently according to the quality finally required for it to be marketed. Air drying is the easiest method to be applied which, together with mechanical milling (kibbling), are used in order to produce a granular material that is much more soluble than the raw product. Other processing methods are spray drying and roller drying. These methods involve dissolving exudates in water under controlled heating conditions and constant stirring. Heating must be mild to avoid distortion of the gum which could have a detrimental effect on its functional properties. After removing the insoluble material by decantation or filtration, the solution is pasteurized and subjected to spray or roller drying. Spray drying involves spraying the solution into a stream of hot air. The water completely evaporates and the dry powder is separated from air by a cyclone, resulting in50 to 100 µm particles. During the roller-drying, the solution is passed to hot rollers and water is evaporated by air flow. The thickness of the resulting GA film is controlled by adjusting the distance between the rollers. The film is separated from the roll by scraping blades giving way to particle scales of several hundred µm in size. GA samples produced by spray drying and drying rollers have an advantage over raw gum as they are virtually free of microbial contamination and dissolve much faster.(Abd-Allah. *et al.*, 2012)

1.2 Chemical Composition and Structure

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

The chemical composition of GA may vary slightly depending on its botanical origin, climate, harvest season, tree age and processing conditions, such as spray dying.(Al-Assaf .*et al*.,2005).

Therefore, there are some differences between the chemical composition of the GA taken from *Acacia senegal* and *Acacia seyal*. In fact, both gums have the same sugar residues but *Acacia seyal* gum has a lower content of Rhamnose and Glucuronic acid and a higher content of Arabinose and 4-O-methyl Glucuronic acid than *Acacia senegal* gum. Instead, *Acacia* seyal gum contains a lower proportion of nitrogen, and specific rotations are also completely different. The determination of the latter parameters may clearly spot the difference between the two species.(Abd-Allah. *et al.*, 2012)

Gel permeation chromatography studies using both refractive index and UV (260 nm) absorption detections have confirmed that both A*cacia senegal* and *Acacia* gums consist of three main components:

i. A main fraction (88-90%) of a polysaccharide of β-(1-3) Galactose, highly branched with units of Rhamnose, Arabinose and Glucuronic acid (which is found in nature like salts of magnesium, potassium and calcium). This fraction is called Arabinogalactan(AG) and contains a low protein content (0.35%) and MW300 kDa.(Renard.*et al.*,2006).

ii. A secondary fraction constituting 10% of the total, with a protein content of 11% and molecular weight of 1400 kDa, corresponding to a complex Arabino galactan-Protein(AGP).(Goodrum.*et al* .,2000).

iii. A smaller fraction (1% of total) composed by a glycoprotein (GP) consisting of the highest protein content (50 wt%) with an amino acid composition different from the complex AGP.(Williams.*et al*.,1990).

Although the total content of carbohydrate fractions of the three components is similar, the protein-rich fractions have a ,significantly, lower glucuronic acid content. Circular dichroism studies conducted on different GA fractions showed that only AGP and GP components have a secondary structure.(Renard.*et al*.,2006).

The AGP fraction was isolated by gel filtration chromatography and subjected to glycolsylation with hydrofluoric acid (HF) to separate the protein.(Qi.*et al*.,1991)

About 400 amino acids form the AGP protein fraction (33% are hydroxyl proline residues). In addition, it was shown that the AGP fraction is composed of blocks of carbohydrates attached to the polypeptide chain by covalent bonds through serine and hydro proline residues .Further SDS-PAGE studies conducted after de glycosylation with HF indicated the presence of two proteins moieties, one with amass of about 30 kDa corresponding to a polypeptide chain of approximately 250 amino acids, and the second one with about 45 amino acids (5 kDa). This minor protein fraction is thought to be associated with the main AG fraction. It was proposed that in the structure of AGP, the polypeptide chain of 400 amino acids acts as "cable connector" of the blocks of carbohydrates ($\leq$ 40 kDa) which are covalently linked to the protein .(Fincher .*et al*.,1983).

1.3 Physicochemical Properties

GA is a heterogeneous material having both hydrophilic and hydrophobic affinities. GA physicochemical responses can be handled depending on the balance of hydrophilic and hydrophobic interactions. GA functional properties are closely related to its structure, which determines, for example, solubility, viscosity, degree of interaction with water and oil in an emulsion.(Abd-Allah. *et al.*, 2012)

1.3.1 Solubility and Viscosity

GA has high water solubility and a relatively low viscosity compared with other gums. Most gums cannot dissolve in water in concentrations above 5% due to their high viscosity.

However, GA can get dissolved in water in a concentration of 50% w/v, forming a fluid solution with acidic properties (pH 4.5). The highly branched structure of the GA molecules leads to compact relatively small hydrodynamic volume and, consequently GA will only become a viscous solution at high concentrations. Solutions containing less than 10% of GA have a viscosity and respond to Newtonian behavior.(Williams.*et al*.,1990)

However, steric interactions of the hydrated molecules increase viscosity in solutions containing more than 30% of GA resulting in an increasingly pseudo plastic behavior. Its high stability in acidic solutions is exploited to emulsify citrus oils. The viscosity of GA solutions can be modified by the addition of acids or bases as these ones change the electrostatic charge on the macromolecule. In very acidic solutions, acid groups neutralize so inducing a more compact conformation of the polymer which leads to a decreased viscosity; while a higher pH (less compact molecule) results in maximum viscosity around pH 5.0-5.5.

In very basic solutions, the ionic strength increment reduces the electrostatic repulsion between GA molecules producing a more compact conformation of the biopolymer and thus reducing the viscosity of the solution.(Anderson .*et al.,*1990)

1.3.2 Emulsifying Properties

GA is well recognized as emulsifier used in essential oil and flavor industries.(Randall. *et al.,*1998).reported that the AGP complex is the main component responsible for GA ability to stabilize emulsions, by the association of the AGP amphiphilic protein component with the surface of oil droplets, while the hydrophilic carbohydrate fraction is oriented toward the aqueous phase, preventing droplets aggregation by electrostatic repulsion.

However, only 1-2% of the gum is absorbed into the oil-water interface and participates in the emulsification; thus, over 12% of GA content is required to stabilize emulsions with 20%. (Abd-Allah. *et al.*, 2012)

1.3.3 Molecular Association

It is well known the tendency of polysaccharides to associate in aqueous solution. These molecular associations can deeply affect their function in a particular application due to their influence on molecular weight, shape and size, which determines how molecules interact with other molecules and water. There are several factors such as hydrogen bonding, hydrophobic association, an association mediated by ions, electrostatic interactions, which depend on the concentration and the presence of protein components that affect the ability to form super molecular complexes. (Al-Assaf.*et al*.,2007).

Molecular associations in GA can lead to an increase in molecular weight in the solid state by maturation under controlled heat and humidity. The process does not involves change in the basic structural components and, while the maturation takes place, the level of association increases giving way to AGP with higher molecular weight and protein content. This process mimics the biological process which produces more AGP throughout the tree growth, and gets maturation to continue during the storage of GA after harvest.(Al-Assaf.*et al*.,2007).

Subsequently analyze the role of protein components in GA to promote molecular association when the gum is subjected to different processing treatments such as maturation, spray drying and irradiation. Results demonstrate the ability of protein components to promote hydrophobic associations that influence the size and proportion of the high molecular weight component AGP. When GA undergoes maturation (solid state heat treatment) there is an increase in the hydrophobic nature of the gum and therefore an increase of its emulsifying properties. Spray drying involves not only the aggregation through hydrophobic associations but also changes in the surface properties of peptide residues increasing GA hydro philicity compared with the association promoted by the treatment of maturity in the solid state. Ionizing radiation in both aqueous solutions and solid state

induces cross-linking between polysaccharide blocks by the formation of –C-C- bonds.(Al-Assaf.*et al*., 2009).

1.4 Pharmacological Action

Although GA is being widely used as an experimental vehicle for drugs in physiological and pharmacological experiments, and it is supposed to be an inert substance. (Trommer.*et al*.,2005)

Recent reports have confirmed that GA has some biological properties as an antioxidant on the metabolism of lipids positive contribution in treating kidney, cardiovascular and gastrointestinal diseases. (Wapnir.*et al*., 2008).

GA has been extensively tested for its properties as non-digestible polysaccharide which can reach the large intestine without digestion; in the small intestine, it can be classified as dietary fiber. Due to its physical properties, it reduces glucose absorption, increases fecal mass, Bile acids and has the potential to beneficially modify the physiological state of humans.(Adiotomre.*et al.*,1990)

GA is slowly fermented by the bacterial flora of the large intestine producing short chain fatty acids.(Annison.*et al.*,1995).

Therefore, its tolerance is excellent and can be consumed in high daily doses without intestinal complications. In addition, GA is able to selectively increase the proportion of lactic acid bacteria in healthy subjects.(Adiotomre.*et al.*,1990)

A daily intake of 25 and 30 g of GA for 21 to 30 days reduced total cholesterol by 6 and10.4%, respectively. The decrease was limited only to LDL and VLDL, with no effect on HDL and triglycerides.(Ross.*et al.*,1983).

The plasma cholesterol concentrations were not affected by the supply of GA, but triglyceride concentration in plasma was significantly lower than in controls.(Topping.*et al.*,1985).

Various mechanisms have been proposed to explain the hypocholesterolemia effect of GA.(Annison.*et al.*,1995)

some studies have suggested that the viscosity of fermentable dietary fiber contributes substantially to the reduction of lipids in animals and humans.(Gallaher.*et al.,*1993).

However, other studies suggested that this property is not related to plasma lipids .(Evans.*et al.*,1992).

The mechanism involved is clearly linked to increased bile acid excretion and fecal neutral sterol or a modification of digestion and absorption of lipids (Moundras.*et al*.,1994).

1.5 Applications

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

1.5.1 Confectionery and Baking

GA is employed in a variety of products including gum, lozenges, chocolates, and sweets. In these products, GA performs two important functions: to delay or to prevent sugar crystallization, and to emulsify fat to keep it evenly distributed throughout the product. In baking, GA is extensively used for its low moisture absorption properties. GA solubility in coldwater allows greater formation of clear solutions than in sugar solutions. It has also favorable adhesive properties to be used in glace and meringues, and it provides softness when used as an emulsion stabilizer. Baking properties of wheat and rye flours can be improved by adding a small amount of GA since its capacity for retaining moisture reduces the hardening of bread.(Abd-Allah. *et al.*, 2012)

1.5.2 Dairy Products

GA is used as a stabilizer in frozen products like ice-cream due to its water absorption properties. The role of GA in these products is to cause a fine

texture and growth by inhibiting the formation of ice crystals which is achieved by combining a large amount of water and holding it as water of hydration, being its higher melting point the main attraction of ice-cream.(Abd-Allah. *et al.*, 2012)

1.5.3 Beverages

GA is used as an emulsifier in beverages such as citrus juices, beer, and cola drinks. GA ability to stabilize foams is used in the manufacture of beer and soft drinks. Besides, it can be used for clarifying wines.(Abd-Allah. *et al.*, 2012).

1.5.4 Micro Encapsulation

In the food industry, micro-encapsulation is an important process to improve the chemical stability of sensitive compounds, to provide the controlled release of micro encapsulated compounds and to give a free flowing powder with improved handling properties. The encapsulating material must preserve and protect the encapsulated compounds during manufacture, storage, and handling to release them into the final product during manufacture or consumption. Solubility and low viscosity emulsion properties have facilitated the use of GA as an encapsulating agent for retention and protection of chemically reactive and volatile commercial food flavoring has as reported on the encapsulation of orange oil using GA as wall material. Its main drawback is its cost for the oversubscription.(Reineccius.1988).

However, due to its efficacy with regard to other wall materials such as malt dextrin and modified starch, reported by various studies the cost may not be relevant as long as extra protection or stability are achieved for microencapsulated high-value products, and in food or pharmaceutical fields.

GA is mainly used for fat micro-encapsulation because it produces stable emulsions in the case of most oils in a wide pH range, and it has the ability to form films (Kenyon,1995).

The study of the photo stability of the micro-encapsulated carotenoid bixin indifferent edible polysaccharide. They found out that microencapsulated bixin in GA was three to four times more stable than the one microencapsulated with malto dextrin and about ten-fold than in homogeneous solvents. (Borbosa.*et al.*,2005).

1.6Antioxidant Action

GA has antioxidant capacity. However, there are controversial results of it. For example, GA has been reported to exert a protective effect against gentamicin and cisplatin nephro toxicity, and doxorubicin cardio toxicity used as biological models in rats. However, the treatment of rats with GA causes only a slight palliative effect of gentamicin nephro toxicity. Later study of lipidper oxidation antioxidant and reducing effects in vitro of various polysaccharides(including GA). (Abd-Allah. *et al.*, 2002).

They found that GA reduces lipid per oxidation of skin in a dose-dependent manner. In contrast, the administration of GA at concentrations of 2.5%, 5.0%and 10.0% in drinking water for eight consecutive days to rats did not significantly alter the concentrations of free radical scavenger's glutathione (GSH) and acid ascorbic acid (AA),and superoxide dismutase (SOD), or lipid per oxidation.(Trommer.*et al*.,2005).

Consequently, the antioxidant activity of GA in biological systems is still an unresolved issue, and therefore it requires a more direct knowledge of the antioxidant capacity of GA that can be obtained by *in vitro* experiments against different types of oxidant species. The total antioxidant activity of a compound or substance is associated with several processes that include the scavenging of free radical species ability to quench active excited states (triplet excited states and/or oxygen singlet molecular 1O2), and/or sequester of metal ions (Fe2+, Cu2+) to avoid the formation of HO. by Fenton type reactions. In the following sections, we will discuss the *in vitro* antioxidant capacity of GA for some of these processes.(Abd-Allah. *et al.*, 2012)

Emulsions are applied in various fields including food, cosmetics, pharmaceuticals, petro-chemicals, and agricultural products. An emulsion is

a thermodynamically unstable system of two immiscible liquids. Emulsions are categorized into two types: oil-in-water (O/W) and water-in-oil(W/O) emulsions. Oil-in-water emulsions are extensively used in food products including milk, beverages, sauces, etc., and oil-in-water emulsions are utilized for delivering lipophilic bioactive compounds such as vitamins and anti-oxidants. The stability of the emulsions is limited by die rent phenomena including coalescence, flocculation, lactation, and Ostwald ripening. The stability of the emulsions can be improved by adding emulsifiers and stabilizers. Poly saccharides are often used as stabilizers and thickeners in the food industry. Polysaccharides, when added to oil-in-water emulsions, increase the viscosity of the aqueous phase, enhance the spatial repulsive force and electrostatic repulsion between the oil droplets, and alter the rheological properties of the emulsion. In recent years, scientists have studied the emulsification properties of many natural polysaccharides such as seaweed poly scarried , pectin , spruce galactomann ansorchid root polysaccharides [basil-seed polysaccharides (Dendrobium, Arabic and Alginate, 2020)

Use of various gums as pharmaceutical excipients is nothing new. As a stabilizer and thickening agent, use of natural gum has been found in the literature about five thousand years back. Some natural or induced exudation of normally neutral or slightly acidic complex of polysaccharides or partially acetylated polysaccharide or heterogeneous polysaccharide are obtained as a mixture with calcium, potassium and magnesium salts. As a natural defense mechanism to prevent infection or dehydration many trees and shrubs are known to produce an aqueous thick exudation when the plants bark is injured. Eventually the solution dries up in contact with sunlight and air and a hard transparent brown-tint glass like mass is formed. This solid exudation is commonly known as natural Gum. Some of the gums used frequently now-a-days as pharmaceutical excipients and /or in food industry are Gum acacia, gum tragacanth, gum Karaya etc. Gum acacia is mainly used in the confectionary industry. Traditionally it is used in candies to provide the appropriate texture so that they do not ad-here to the teeth. Gum acacia is used in chewing gu m as a coating agent. And is lso used as emulsifier in soft drink industries. Pharmaceutically gum acacia is still used

as a suspending agent, emulsifier, adhesive and tablet binding agent..(Samanta . *et al*., 2010)

In cosmetic industry it is used as a stabilizer in lotions and protective creams, where it increases viscosity, imparts spreading properties and maintains a protective coating.(Whistler ,.*et al* .,1993).

Gum tragacanth is used in ice creams to provide texture to the product and acts as a thickener and pro-vides texture for chewy sweets such as lozenges. Gum tragacanth is widely used in pharmaceutical industry as an effective suspending agent. Gum tragacanth is used as a stabilizer in dermatological creams and lotions and it also provides a protective coating. Suspending properties are used in jellies and tooth paste giving spread ability and a shiny creamy appearance. .(Samanta, *et al.*, 2010)

Gum Karaya is well-studied for stabilizing low pH emulsion such as sauces. Due to the water binding capacity of Gum karaya it extends the shelf-life of baked goods. It is widely used as stabilizer, thickener, texturizer and emulsifier in foods. Powdered Gum karaya is widely applied on dental plates as an adhesive.(Steinhardt, A .*et al* .,1962)

It is used as a bulk laxative, and also used as an adhesive in leak-proof sealing rings for post-surgical drainage pouches or ostomy bags and in skin lotions (Marsan, A.*et al* .,1967)

1.7 Emulsion Formation

The first step in the formation of a stable emulsion is dispersion of one liquid phase in another liquid phase. A critical factor in that emulsification process is the formation of a monomolecular layer at the lipid/water inter phase. During emulsion formation there is a large increase in surface area (up to several thousand fold), which is dependent upon the number and size of the droplets. To form and disperse these droplets, a substantial amount of energy or work must be supplied. Since emulsifiers reduce the surface tension, the addition of emulsifiers reduces the amount of work that must be done to form the emulsion. The most common method of emulsion formation is the application of mechanical energy via vigorous agitation.

The emulsifier is first dissolved in the aqueous or organic phase depending on the solubility of the emulsifier and on the type of emulsion desired.

Next, sufficient agitation to cause surface deformation and large droplet formation is applied during the addition of one phase to the other. The next step is the disruption of droplets. To form a stable emulsion and prevent coalescence, sufficient amount of emulsifier must be available to adsorb at the aqueous/organic inter phase. The emulsifier lowers the Laplace pressure, which facilitate droplets deformation and disruption. After droplets formation, the emulsifier partitions into the inter phase of the aqueous/organic system stabilize the emulsion. Droplet size, which is, directly, related to the emulsification procedure, depends on the amount of emulsifier added, the type of emulsifier, and the emulsification temperature. There are several possible methods for emulsion formation and a wide range of equipment is available for emulsion formation.

These methods include shaking, stirring, and injection, and the use of colloid mills, homogenizers, and ultrasonic.(walstra.*et al*.,1983).

1.8 Characterization of Emulsion

1.8.1 Viscosity of Emulsion

Dynamic viscosity of the prepared emulsion was measured using Brook-field rotational viscometer TV-10 (Toki San-gyo Co. Pvt.Ltd, Tokyo, Japan) rotated at 60 rpm for one minute. The length and diameter of the cylinders were 10.5 cm and 3 cm respectively. Length and diameter of the spindles were 6.4 cm and 1.8 cm respectively. (Samanta, Ojha and Mukherjee, 2010).

1.8.2 Test for Identifying Emulsion Type (Dye Test)

Several tests are available for distinguishing between o/w and w/o type emulsions. They include tests of miscibility, dye test, electrical conductivity measurements etc. (Samanta, Ojha and Mukherjee, 2010).

1.8.3 Dye Test

Prepared emulsion (10 ml) was triturated with Sudan III (0.05 g) and a drop of it was placed on a microscope slide, covered with a cover-slip and examined under a microscope. (Samanta,Ojha and Mukherjee ., 2010) .

1.8.4 Cracking of Emulsion

This involves coalescence of the dispersed globules and separation of the disperse phase as a separate layer. Re-dispersion cannot be achieved by shaking and the advantages of emulsification are lost and accurate dosage is impossible. Simple visual observation (of the stored samples about 24 months) was the means to detect cracking. (Samanta, Ojha and Mukherjee., 2010).

1.8.5Creaming of Emulsion

Creaming may be defined as the formation of a layer of relatively concentrated emulsion and this conditions favors breakdown of the interface and consequent coalescence of the oil globules and therefore, the emulsion may eventually crack. By shaking, creaming may disappear in many cases. Simple visual observation technique (of the stored sample about 24 months).(Samanta, Ojha and Mukherjee, 2010).

1.9 Basic Preparation Method

The process of converting bulk oil and bulk water into an emulsion, or of reducing the size of the droplets in a preexisting emulsion, is known as homogenization. It can be carried out by using the homogenizer, such as a high shear mixer, a high pressure valve homogenizer, a colloid mill or an ultrasonic homogenizer, to apply intense mechanical agitation to a liquid mixture.(Dickinson.*et al*., 1992).

Conventional emulsions are, inherently, thermodynamically unstable systems because the contact between oil droplets and water molecules is unfavorable, and they are intended to breakdown over time.(Dickinson.*et al*., 1992).

In this case, in order to prepare emulsions that are kinetically stable over time (a few days, weeks, months or years), emulsifiers and stabilizers are required. An emulsifier is a surface-active substance that adsorbs to the surface of emulsion droplets to form a protective coating that prevents the droplets from aggregating with one another, but they do have different emulsifying mechanisms. Gum *Acacia*, an amphiphilic that is a mixture of anionic polysaccharides and protein fraction, tends to stabilize emulsions primarily through electro static interactions and Leser. Octenyl succinic anhydride (OSA) modified starch, is composed of starch molecules that have been chemically reacted with Octenyl succinic anhydride to give some hydrophobic character. Whey protein isolate is a mixture of amphoteric globular protein and polysaccharides, and tends to stabilize emulsions primarily through electrostatic interactions. (Dickinson.*et al.*, 1992).

1.10 Objectives of the study

- The study aimed to investigate the effect of heat treatment for different time interval on some of the physicochemical properties of spray dried *Acacia* gum and the impact of this treatment on its functionality .

Specific objectives:

1- To investigate the effect of heat treatment of gum Arabic spray dried powder for different periods of time on :
   - Gum solution pH .
   - Ash content .
   - Optical rotation
   - Solution viscosity

2- To investigate the effect of heat treatment for varied period of time of the spray dried gum Arabic powder sample on the stability of their oil - in - water emulsions.

Chapter Two

Materials and Methods

2. Materials and Methods

2.1 Materials

- The material use in the study has been supplied by *Henelie* Co.LTD Khartoum Sudan in form of spray dried powder of gum Arabic *Acacia senegal* gum and *Acacia seyal* gum ,one Kg. of each gum species . These were high quality gum grades, fully sterile and suitable for application in food or pharmaceutical industries.
- De ionized water.
- Sesame oil (Alnasr company).
- Distilled water.

2.2 Methods

2.2.1 Heat Treatment *Acacia* Spray Dried Gum

(50g) of Gum samples were heated at 150º for 17, 48 and 72 hours in oven. (Glyn *.et al*., 2011).

2.2.2 Total Ash Determination

(1.0g) of gum was weighted in Ignited crucible, it was ignited in muffle furnace at 600° ± 50° for 6 hours until the residue is completely incinerated, the crucible was cooled in a desiccators with silica gel, the weight of the sample was recorded and the percent of total Ash was calculated.(M.Gundidza.*et al.*,2011)

$$\text{Total ash} = \frac{weight\ of\ ash}{weight\ of\ sample} \times 100$$

2.2.3 Determination of pH

(10g) of gum were that was preheated for different time interval(150°) sample was dissolved in 100 ml of de ionized Water, it was mixed thoroughly until dissolved completely , The samples were kept in the refrigerator for 30 minutes , the pH of each sample was measured at 20 °C using pH meter (Janway 3510).

2.2.4 Determination of Optical Rotation

(0.1g) of each heat treated sample was dissolved in 100 ml of de ionized Water, it was Mixed thoroughly until dissolved completely. (Miguel *et al.*, 2016).The samples were kept in the refrigerator for 30 minutes, the optical Rotation of each sample was measured at 20 °C (Bellingham Stanley ADP430).

2.2.5 Determination of Viscosity

(10 g) of each heat treated sample was dissolved in 100 ml of de ionized Water, and Mixed thoroughly until dissolved completely. (Miguel *et al.*, 2016).
The solutions were kept in the refrigerator for 30 minutes, the viscosity of each sample solution was measured at 20°C using viscometer (Anton par 100).

2.2.6 Stability of Emulsion

2.2.6.1 Preparation of Gum Solution

Gum solution (5%) was prepared by dissolving 5 g of *Acacia* gum in 95 ml distilled water, the solution was stirred until completely dissolved , the percent verified by refracto meter. (Miguel *et al.*, 2016).

2.2.6.2 Preparation of Oil-in-Water Emulsions

Gum solution (5%) was mixed with sesame oil in a ratio of 80: 20 W/W, respectively, using a blender for 10 minute at 3500rpm. The mixture was diluted by distilled water in a ratio of 1:100).(Omer *et al.*, 2015).

2.2.6.3 Study the Stability of the Oil-in-Water Emulsions

The absorption was measured by UV Spectrophotometer at λ max of 520nm at different time.(Omer *et al.*, 2015).

To follow the stability of the emulsion over time, the light absorption of the diluted emulsion was measured for the freshly prepared emulsion (zero time). Then emulsion was allowed to stored under suitable condition.

The absorption of emulsion was subsequently measured at regular time intervals of 24 hours four times (zero time, after 24, 48 and 72 hours).

The stability of emulsion was estimated as a ratio of the absorption of emulsion at time (t) to that when time is zero $t_{\circ}$.

Emulsion stability index (SI) $= \frac{absorbance\ at\ (t_{\circ})}{absorbance\ at\ (t)}$

Chapter Three
Results and Discussion

3. Results and Discussion

3.1 Ash Content

Table 3.1and Figure 3.1 is shown the Ash content of *Acacia Senegal* and *Acacia seyal* samples (control and heat –treatment). Comparing the Ash content result of the control sample and that of the heat- treated sample , shows that there is no significant change in the value of these result and the average of this results is around 2.5% and 2.1% for *Acacia senegal* and *Acacia seyal* gums respectively . This result is obviously expected, since most of the minerals forming the ash are stable at the temperature range used for treating the samples (≤160ºC).

Further the ash content results obtained in this study agree with results of many researches cited in the literature (Anderson.*et al.*,1993), (Okalebo. *et al*., 2002).

Table 3.1: Ash content value of *Acacia senegal* and *Acacia seyal* samples heat treated at 150°C for different times intervals.

Heat – treatment time /hours	**Ash content % w/w**	
	Acacia senegal	***Acacia seyal***
0	2.3%	2.7%
17	2.7%	1.5%
48	2.4%	1.9%
72	2.6%	2.3%

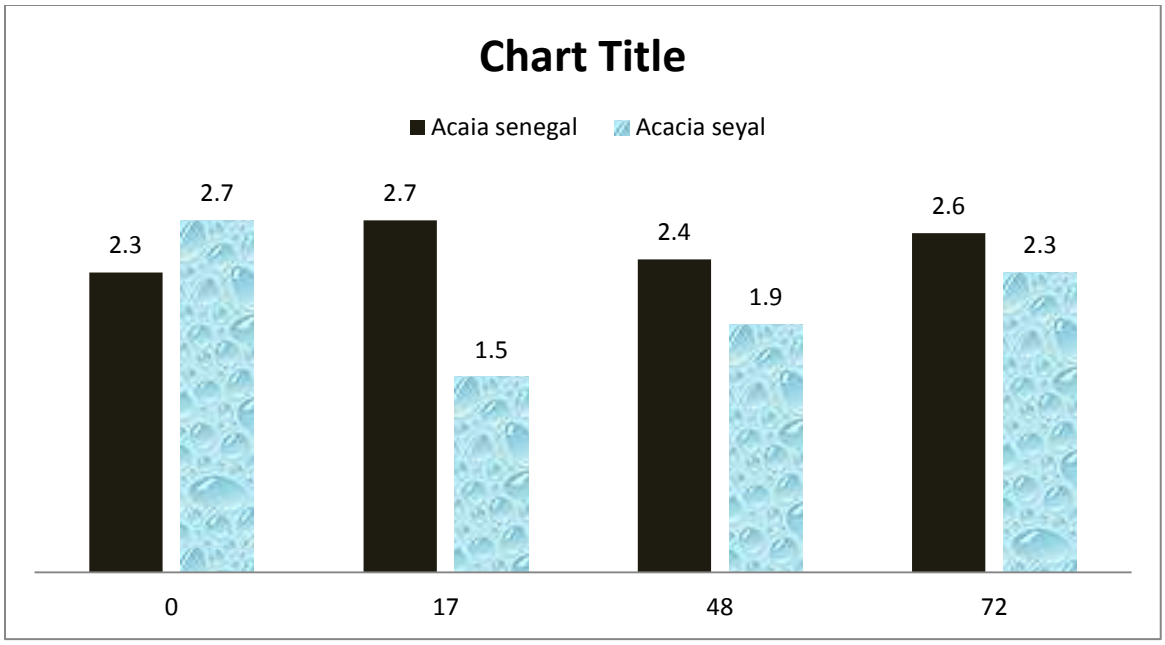

Fig3.1: Ash content of *Acacia senegal* and *Acacia seyal* samples heat –treatment at different Time /hours.

3.2 Effect of Heat – Treatment of *Acacia senegal* and *Acacia seyal* Gum on pH:

Table 3.2 and Figure 3.2 is shown the pH measurement results for the control and heat-treated *Acacia senegal* and *Acacia seyal* gum sample . It clear that the heat-treatment of both *Acacia senegal* and *Acacia seyal* gum had not altered the pH value and for both gums it remained within the characteristic value, known from previous studies, mild acidic range, that fall between 4.6 - 4.4 for both gums.

Table 3.2: pH value of *Acacia senegal* and *Acacia seyal* samples heat treated at 150°C for different times intervals.

Heat – treatment time /hours	pH	
	Acacia senegal	*Acacia seyal*
0	4.6	4.4
17	4.4	4.6
48	4.4	4.4
72	4.4	4.4

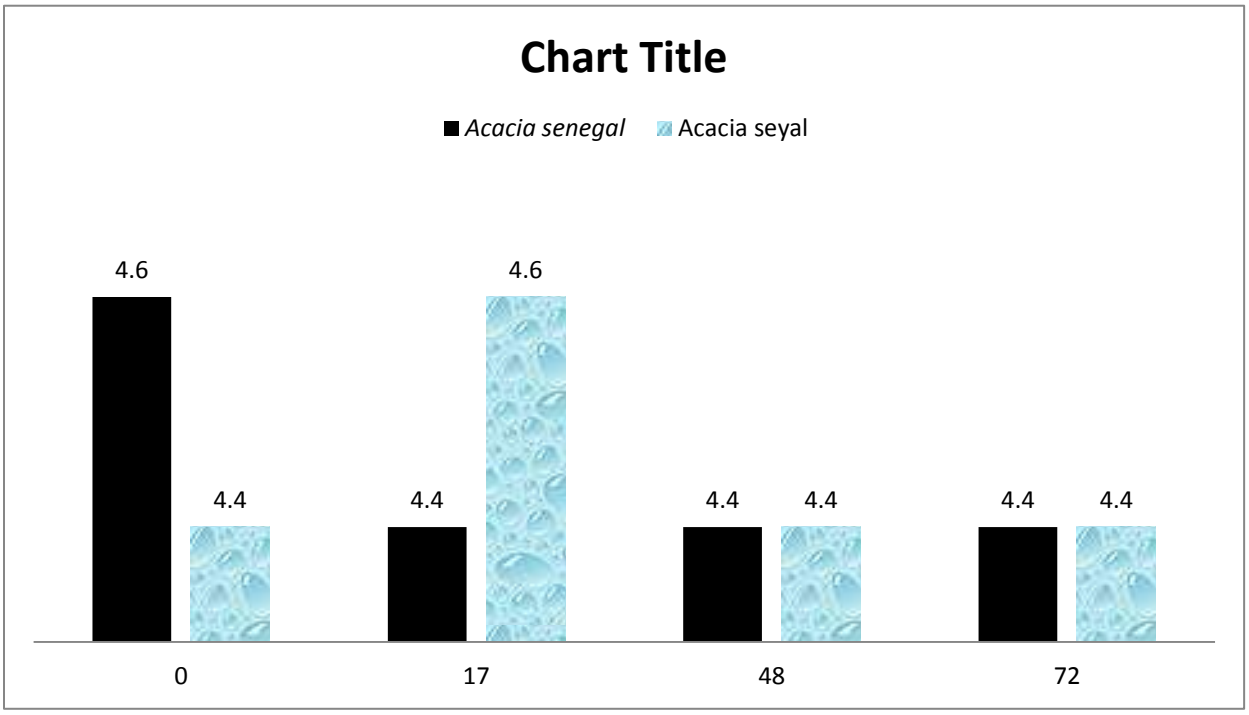

Fig 3.2: pH of *Acacia senegal* and *Acacia seyal* samples heat –treatment at different Time/hours.

3.3 Optical Rotation Values

Table 3.3 and Figure 3.3 is shown the Optical rotation measurement of the *Acacia* gums under study. The values obtained for both control samples of *Acacia senegal* and *Acacia seyal* agree very well with the value cited in the literature and conform the botanical source of these gum species. The optical rotation of *Acacia senegal* is negative in agreement with the well established character of *Acacia senegal* being levo rotatory and belong to vulgarize series according to Bentham taxonomica classification. While *Acacia seyal* possessing positive optical rotation, dextro rotatory, and belong to series gumifera. according to Bentham classification. Interestingly the heat – treated sample acquired quite different values of optical rotations in both gums. In spite of the significant change in the value of the optical rotation, both samples retain their prosperities as levo gyrate in case of *Acacia senegal* and dextro gyrate in the case of *Acacia seyal* .The change in the value of the specific optical rotation may be due to new conformations at molecular level for both gums species rendered possible at higher temperature.

Table 3.3: Specific optical rotation value of *Acacia senegal* and *Acacia seyal* samples heat treated at 150°C for different times intervals.

Heat – treatment time /hours	**Specific optical rotation(degree $mlg^{-1}dm^{-1)}$**	
	Acacia senegal	***Acacia seyal***
0	-30	+55
17	-26.77	+317.50
48	-12.50	+239.00
72	-10.00	+314.50

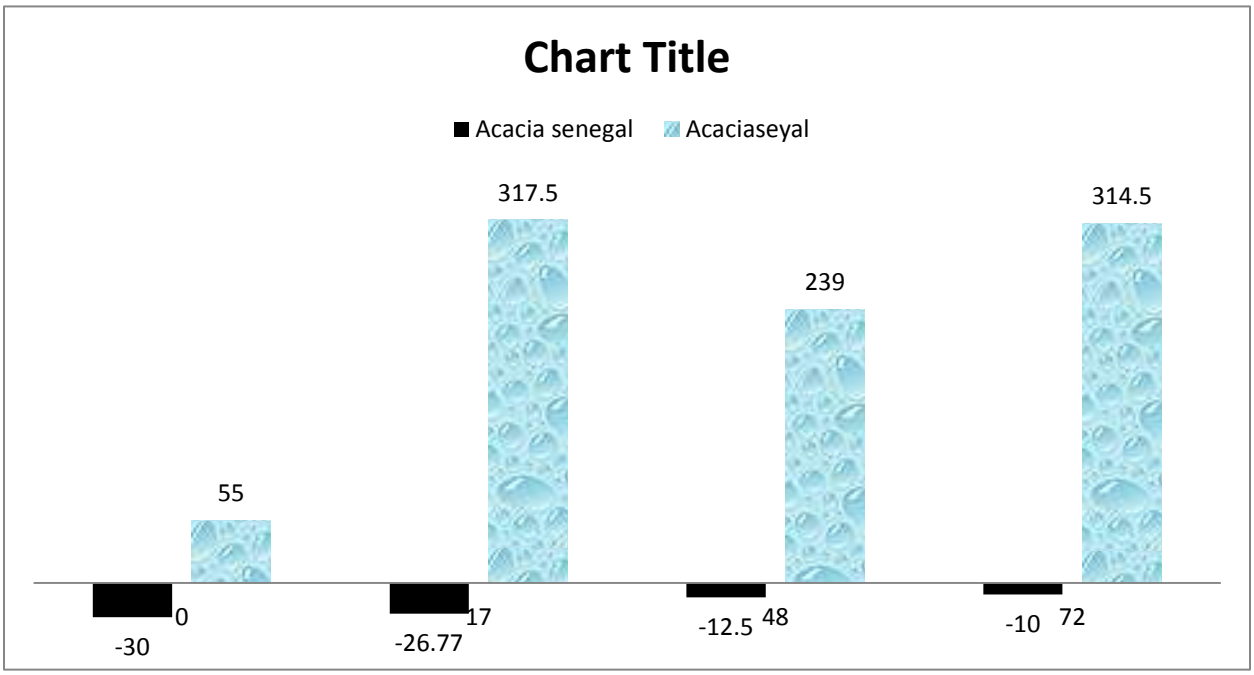

Fig 3.3: Specific optical rotation of *Acacia senegal* and *Acacia seyal* samples heat –treatment at different Time/hours.

3.4 Effect of Heat-Treatment on the Viscosity Value of *Acacia senegal* and *Acacia seyal* Gum Samples:

Table 3.4 and Figure 3.4 was shown the trends of change in values of viscosity with time of heat-treated gums. The viscosity of the control sample was as low as 35 and 41 cps for both *Acacia senegal* and *Acacia seyal* gum respectively. These results agree with the typical known qualities of gum Arabic, which are known for their law solutions viscosity compare to other exudate gums such as *Acacia senegal* var *senegal*, keresis , karaya gum or Xanthan gum.

The results also show very drastic changes in viscosity of heat-treated samples for both *Acacia senegal* and *Acacia seyal* gum. The viscosity change of heat-treated sample of *Acacia senegal* ranged for 494% for sample subjected to heat-treatment for 72 hours, to 1426%. The same trend is also shown by *Acacia seyal* heat-treated samples where is the sample heated for 17 hours the viscosity reach 1226% compared to control sample. Also the sample of *Acacia seyal* heated for 48houres

showed an un presented increase in viscosity that reach 4731%, one order magnitude. This is a clear indication that some changes at the molecular level had occurred while heating the gum sample in the solid state. These changes may be a result of loss of tertiary structure of the protein of the gum molecule for sample subjected to heat treatment for 48 hours , or it may be due to some cross linkage at the intra or inter molecular level, that changed the shape and size of the gum macro- molecules and hence its viscosity. (Hassan.*et al.*,2005) had reported that the radius of gyration of *Acacia senegal* gum is 34nm and that of *Acacia seyal* is 28nm, while intrinsic viscosity are 16mL g^{-1} and 11 mL g^{-1} for the gums respectively. They both posses globular compact structure in their solutions. This finally may explain the low viscosity of the gum solution which is influenced by the shape and size of the molecules as well as their molecular weight. Molecule that assumed globular structure in their solution, will posses lower viscosity compared to molecules of chain like molecule of the same molecular weight. Further considering the model of structure proposed for *Acacia* gum molecule, the heat- treatment might de-nature the protein moiety of the gum molecule and consequently allow for extension of the carbohydrate moieties in space, hence change the size and shape of the molecules resulting, ultimately, in an increase of the solution viscosity.

Table 3.4: Viscosity value of *Acacia senegal* and *Acacia seyal* samples heat treated at 150°C for different times intervals.

Heat – treatment time /hours	**Viscosity**	
	Acacia senegal	***Acacia seyal***
0	35 cps	41 cps
17	498 cps	503 cps
48	4991 cps	1940 cps
72	173.4 cps	1094 cps

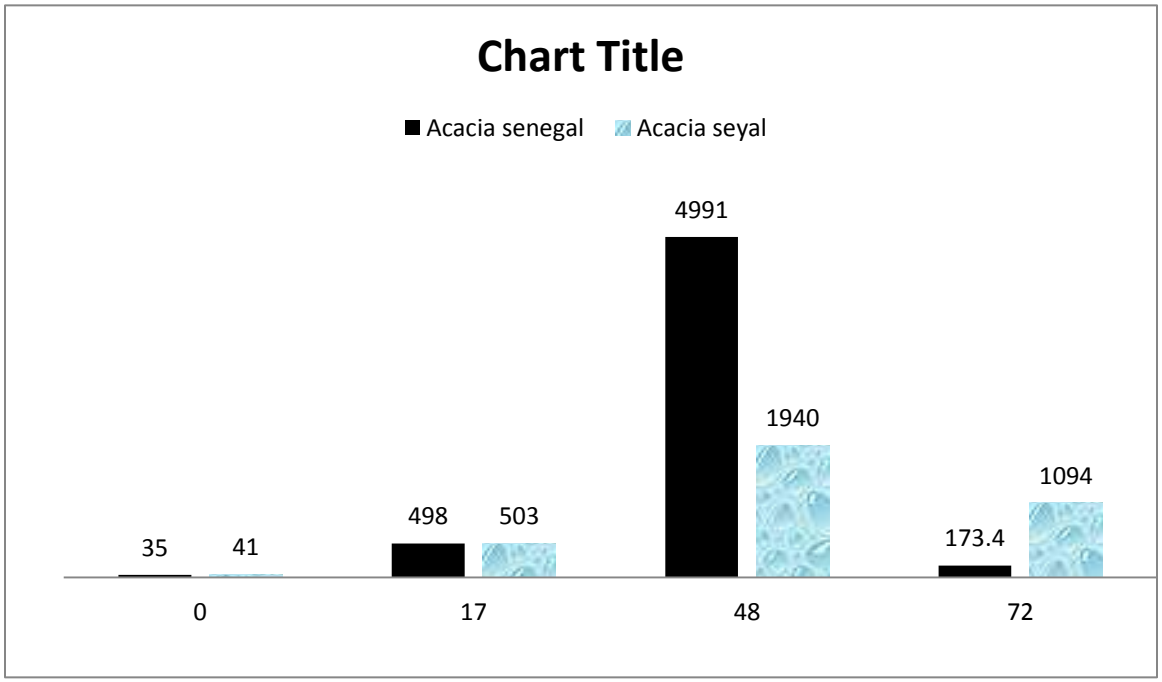

Fig 3.4: Viscosity variation between *Acacia senegal* and *Acacia seyal* samples heat –treatment at different Time/hours.

3.5 Stability of Heat –Treated *Acacia senegal* and *Acacia seyal* Gum Emulsions

Oil in water emulsions was prepared using heat-treated *Acacia senegal* and *Acacia seyal* gums. The functional qualities of the emulsion were followed in terms of stability index (SI) while in the parameter that reflect the stability of the emulsion as a function of time. The absorbance of emulsion was determine for a highly diluted aliquot (1:100) and the absorbance was measured at (0,24,48 and 72 hours) .The stability index was calculate as a ratio of absorbance of freshly prepared emulsion i.e. at zero time to the absorbance of the emulsion at time(t). The satiability index (SI) is calculate as:

$$SI = {}^{A_\circ}\!/_{A?}$$

Where: A_0 is the absorbance of the emulsion at time (t_0)

A_t is the absorbance of the emulsion at time (t)

Table 3.5 and 3.6 show the stability of the emulsions in all cases decreased with time compared to emulsion stability at zero time. The emulsion stability of *Acacia senegal* gum heated at 150°C for 72 hours after 72 hours is higher in stability compare to *Acacia senegal* gum heated at 150°C for 17 and 48 hours. Figure 3.5 show that the emulsion stability index of *Acacia* Senegal gum decreased with time. The stability of emulsion in all case decreased with time compare with emulsion stability at zero time. The emulsion stability of *Acacia seyal* gum heated at 150°C for48 hours is higher compared to *Acacia seyal* gum heated at 150°C for 17 hours . Generally it is found that the emulsion stability index of *Acacia seyal* gum decrease with time.

Table 3.5: Emulsion stability index of *Acacia senegal* gum emulsion

Emulsion stability index	***Acacia senegal*0**	***Acacia senegal*17**	***Acacia senegal*48**	***Acacia senegal*72**
Fresh prepared	1	1	1	1
24 hours	0.88	0.92	0.84	0.82
48 hours	0.78	0.69	0.73	0.79
72 hours	0.40	0.44	0.41	0.68

Table 3.6: Emulsion stability index of *Acacia seyal* gum emulsion

Emulsion stability index	*Acacia seyal* 0	*Acacia seyal*17	*Acacia seyal*48	*Acacia seyal*72
Fresh prepared	1	1	1	1
24 hours	0.89	0.78	0.92	0.85
48 hours	0.70	0.69	0.52	0.49
72 hours	0.40	0.57	0.46	0.43

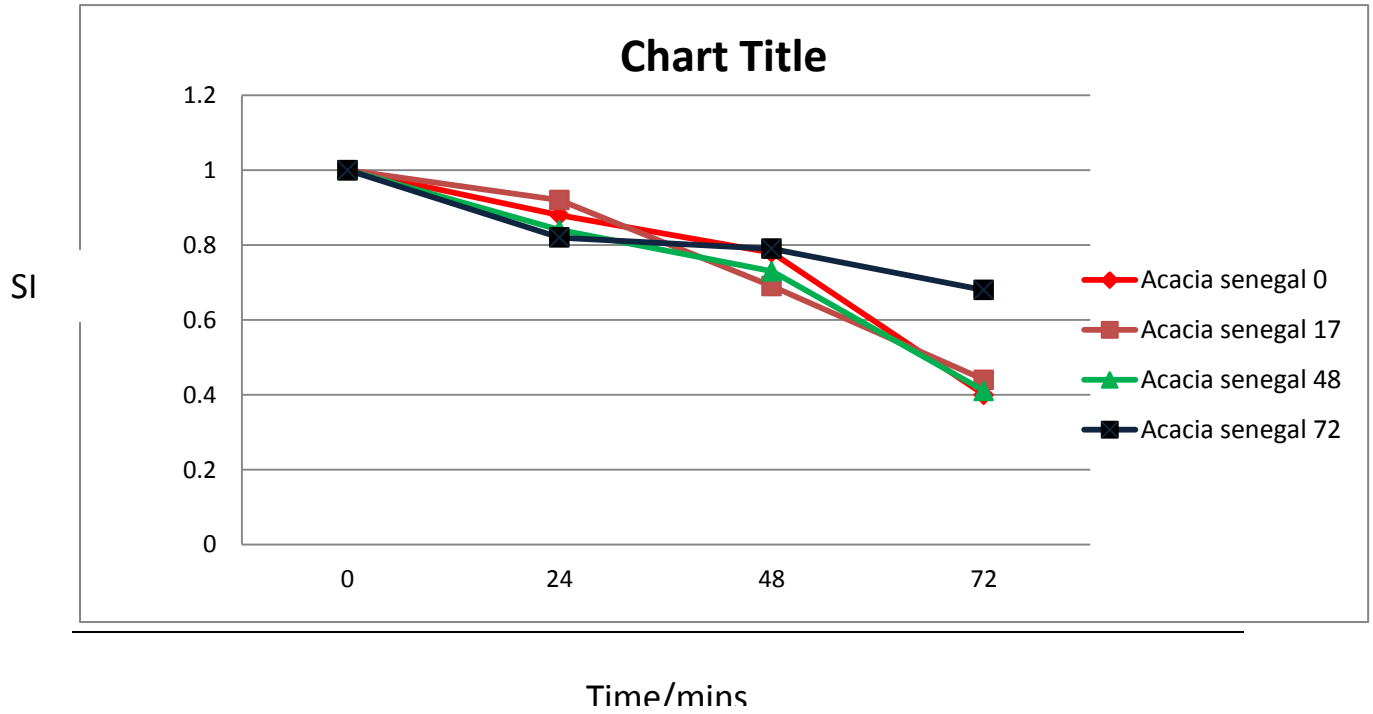

Fig 3.5: stability index of *Acacia senegal* emulsion heat- treated for different time at 150°C(SI) Vs time .

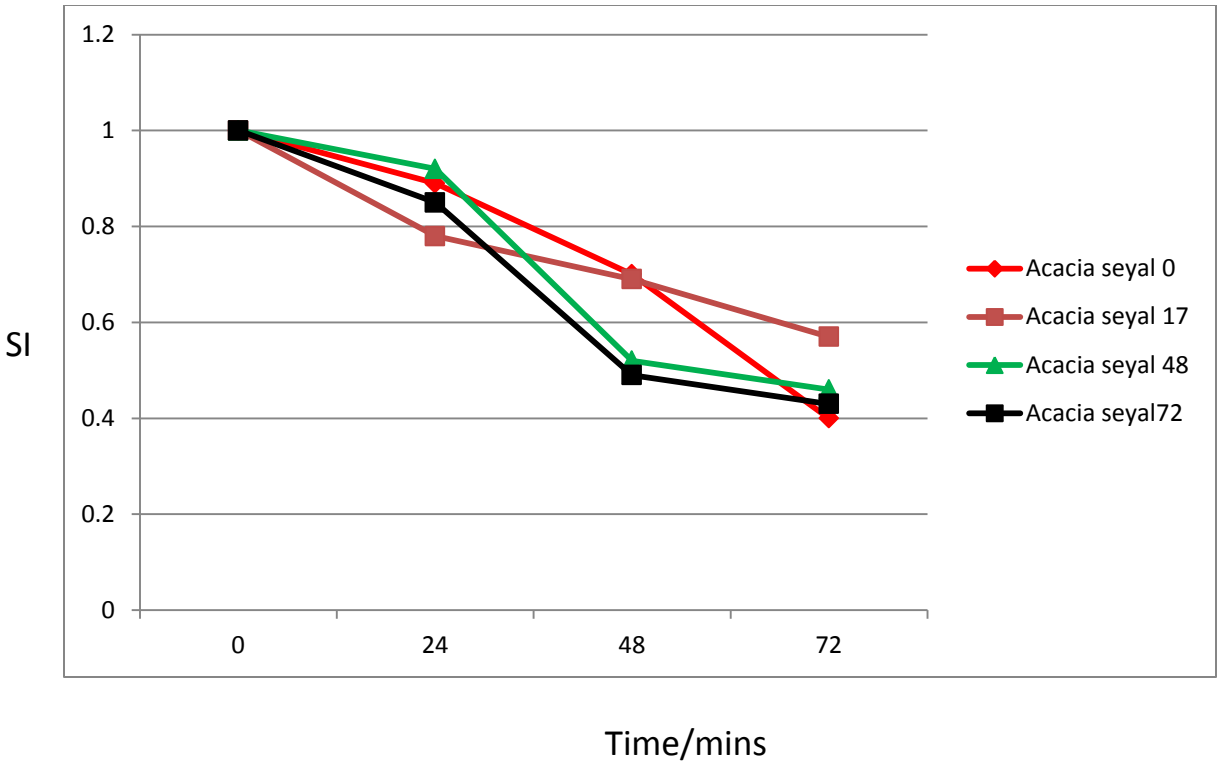

Fig 3.6: stability index of *Acacia seyal* emulsion heat- treated for different times at 150°C (SI) Vs time.

3.6 Conclusion

Heat treatment of solid gums had no effect on the pH and total ash content of gums.

Heat treatment of the *Acacia* gum in spray dried powder form resulted in improvement of its emulsion stability when heated is done for 72 hours at 150°C for *Acacia senegal* and at 17hours for *Acacia seyal*.

Heat treatment of gum Arabic spray dried powder for 150 °C resulted in negative increase in the viscosity of aqueous solutions of there gum, suggesting occurrence of some rearrangement at the molecular level of some aggregation among the molecular moieties.

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3.7 Recommendations

Heat treatment of gum Arabic in the solid state is recommended if to increase the viscosity of the aqueous solution obtained for it.

Optimization of study by wide range of data

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