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EVALUATION THE EFFECT OF PROCESSING OF ACACIA SENEGAL GUM ON ITS PHYSICOCHEMICAL AND FUNCTIONAL PROPERTIES

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ABSTRACT

Gum arabic obtained from *Acacia senegal*, var. *senegal* is considered the oldest and best known of all natural gums . It is known as an important article of commerce for about 4000 years ago. It possesses physicochemical characteristics and functional properties that make it unique in the international trade of food, pharmaceutical, textile, and other industries. This gum is produced from the stems and branches of *Acacia senegal* tree by a biosynthesis process called gummosis. Gum collection can be done by simple gathering of nodules that have oozed from the tree. Sudan classifies *acacia Senegal* gum into different grades. The crude exudates of *acacia Senegal* are processed differently according to the quality finally required for it to be marketed. The quality and applicability of well characterized materials are directly related to their physical and chemical properties. In this study physicochemical property of five grades - two crude gum and three processed gums - of *acacia Senegal* have been evaluated to find if processing affect these properties. The results revealed that processing *of acacia Senegal* gum improves its purity and without affecting its chemical composition and functional properties.

KEYWORDS: acacia Senegal, Arabic gum, physicochemical properties, functional properties, raw gum, gum processing.

INTRODUCTION

Gum arabic, also known as acacia gum, has been defined by the Joint FAO/WHO (Food and Agricultural Organization of the United Nations/World Health Organization) Expert Committee for Food Additives (JECFA) as: “a dried exudate obtained from the stems and branches of *Acacia Senegal (L.) Willdenow* or *Acacia Seyal (Fam. Leguminosae)*” FAO (1999). Arabic gum is the oldest and, apparently, best known of all natural gums (Verbeken, Dierckx, & Dewettinck, 2003). The chemical composition of GA is complex and consists of a group of macromolecules characterized by a high proportion of carbohydrates (~97%), which are predominantly composed of D-galactose and L-arabinose units and a low proportion of proteins (<3%) (Islam et al., 1997).

The first known uses of gum arabic were in the ancient Egypt as early as 2000 BC in embalming mummies and paints for hieroglyphic inscriptions (Seif el Din and Zaroug 1996; Elmqvist et al., 2005).Gum Arabic has been known for many thousands of years and there are no artificial substitutes that match it for quality or cost of the production (Gabb, 1997).The gum is produced from the stems and branches of *Acacia senegal* tree (4-15 years old) by a biosynthesis process (gummosis), when subjected to stress conditions such as drought, poor soil or wounding (Barbier, 1992).

Gum collection can be classified into simple gathering of nodules that have oozed from the tree or deliberate tapping of trees where the collector makes a cut and returns to the tree several days later to harvest the gum (Okatahi and Onyibe, 1999). Gum arabic 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 arabic include adhesives, textiles, printing, lithography, paints, paper sizing and pottery glazing (Idris et al., 1998).

Sudan classifies *acacia Senegal* gum into different grades according to nodule size, purity and other physical properties (table 1).

Table 1: Sudan classification of gum Arabic.

Grade	Description	% at sorting
Hand picked Selected	Cleanest, lightest colour, and whole nodule, Ø >30 mm; most expensive grade	0 to 5
Cleaned amber and sifted	Clean and siftings are removed, pale to dark amber colour, whole or broken nodule, Ø >20 mm	5-10
Cleaned	Standard grade, contains siftings but dust is removed, whole nodule plus fragments, 10 <Ø<20mm	70

Siftings	Fine particles left after sorting, contains sand, bark and dirt, 2.5< Ø<10 mm	5
Dust	Very fine particles collected after the cleaning process, Ø< 2.5 mm	5
Red gum	Dark and red particles, only for local use	

Ø – Diameter

Source: MACRAE and MERLIN (2002), WILLIAMS and PHILLIPS (2009)

Processing of Gum Arabic

World-wide, gum processing started in 1970 and high standard quality gums (microbiologically clean and readily soluble) have been produced. Before that gum arabic was sold in its natural form after being cleaned (Osman 1993). In Sudan, gum processing started in 1993 by Gum arabic Company (GAC), it is processed in kibbled form.

1. Kibbling

Kibbling is a process to produce a small granule of gum of more uniform size by using a hammer mill and then screening the large cleaned gum nodules. This type is more preferred by end users because it is more easily dissolved in water than raw gum (Osman 1993).

2. Mechanical powder

In this process either raw or kibbled gum can be used. They are crushed in a swinging hammer mill and thrown against a surrounding cylindrical or polyhedron screen; the product is a fine powder having the size of the screen apertures. The disadvantage of this process is that the last remain of finely divided foreign matters is difficult to remove (Coppen 1999).

3. Spray drying

In this process the gum is firstly dissolved in water and then filtered or centrifuged to remove impurities of the solution (Coppen 1999). To remove the microbial contamination, the solution is pasteurized, and then sprayed into fine droplets by atomization stream of hot air to promote evaporation of the water (Osman 1993). The gum arabic powder, which is produced by spray drying techniques, can be adapted to a wide range of scales (from feed rates of a few kilograms per hour to over 100 tones per hour). This is considered as one of its advantages, but the disadvantage of the process is that it is an energy-intensive process that increases the cost and the requirement for large quantities of pure water (Salim 2000).

4. Roller drying

This process is similar to spray drying but here the filtration or centrifugation of the solution is done in contact with hot rollers. The film of gum left after evaporation of the water is scraped off continuously to produce flakes or powder (Coppen 1999). The disadvantage of this process is that the high temperature used for heating the roller surface could denature the protein and alter the characterization of the gum (Osman 1993).

The physicochemical properties of a compound are the measurable physical and chemical characteristics by which the compound may interact with other systems, and these characteristics collectively determine the quality, applicability or end-use of the compound (Chikamai, 1997; Idris et al., 1998; NGARA, 2005; Elnour et al., 2009).

The physical properties of gum arabic, established as quality parameters include moisture, total ash, volatile matter and internal energy. Gum arabic is a natural product complex mixture of hydrophilic carbohydrate and hydrophobic protein components (FAO, 1990).

The four grades of gum arabic currently exported from Sudan

(a) Hand Picked Selected (HPS): are raw globules of clean gum arabic specially sorted and graded. It represents 10 percent of export which goes mostly to Japan for further processing into powder.

(b) Kibbled (including the cleaned grade): The Sudanese Standard and Metrology Office (SSMO) has established two specifications for kibbled gum: (a) kibbled grade: granules with a maximum size of 14 mm and a minimum size of 3mm and a maximum range of 8mm; and (b) the cleaned grade: gum lumps broken manually, with no limit on the granule size. The clean grade is considered raw gum by buyers; it constitutes GAC’s main export.

(c) Mechanical powder: It is less energy consuming than spray drying, therefore cheaper to produce and less subject to bacterial contamination.

(d) Spray dried powder: Spray drying produces free-flowing powder with high solubility.

The objectives behind this research are to study the effect of *acacia Senegal* gum processing on different physicochemical properties of this gum and to evaluate the effect of processing on functional properties and uses in different industrial applications.

MATERIALS AND METHODS

MATERIALS

Acacia Senegal gum samples

Five samples of crude and processed gum arabic were collected for analysis, they were:

Hand Picked Selected (HPS): was obtained from gum arabic company Ltd (GAC) Sudan. HPS represents raw acacia Senegal gum**.**

Cleaned, was obtained from gum arabic company Ltd (GAC) Sudan.

Kibbled: kibbled 107 of mesh <6mm was obtained from gum Arabic company Ltd (GAC) Sudan.

Mechanically powder Acacia Senegal gum was obtained from the Gum Arabic Company Ltd (Sudan).

Spray-dried gum was obtained from DAL Group Company (Sudan)**.**

METHODS

Preparation of samples

The acacia senegal samples used in this study were supplied by exporting companies from the products prepared for exportation.

Sample preparation

The samples of Hand Picked Selected (HPS),Cleaned and kibbled were stored in clean, labeled self sealed polyethylene bags and grounded to fine powder and passed through a 212μm mesh screen using a mortar and pestle just before each experiment.

Analytical methods

Each analysis was repeated three times, and values reported in respect of the gum samples are actually the average of three replications.

Physicochemical analysis

The physicochemical properties of the gum analyzed include shape, color, solubility, moisture content, ash content, acid insoluble ash, pH determination, specific optical rotation, refractive index, intrinsic viscosity, volatile mater, internal energy, tannin content, nitrogen content, protein content, uronic acid content, sugar content, total soluble fiber and cationic composition. The laboratory procedures used for the analysis of physicochemical properties of the gum Arabic samples are presented as follows:

1. Solubility

Solubility was obtained by dissolving 1g of sample (W) in 100 ml of each of the following solvents, distilled water, ethanol, chloroform and acetone in 250 ml conical flask, then stirred for 30 minutes by magnetic stirrer and the solution filtered through filter paper No. 41, which was weighed before filtration (W1). The filter paper and contents were then dried at 105°C for 30 minutes, cooled and weighed (W2).

The solubility was calculated as percent according to the following equation:

$$S\% = \frac{W - (W2 - W1)}{W} \times 100\%$$

Where:

S = Solubility

W = Weight of sample

W1 =Weight of empty filter paper

W2 = Weight of filter paper + insoluble maters

2. Moisture content (%)

2 g of ground *acacia senegal* sample was weighed and oven dried at 105 ^{o}C for 5 h. Oven dry weight was taken after allowing the samples to cool in a desiccator before reweighing. Moisture content was expressed as a percentage of the weight loss from the original weight (FAO, 1999).

$$\text{Percentage moisture content} = \frac{\text{weight of water evaporated in grams} \times 100}{\text{Weight of sample in grams}}$$

3. pH determination

A 25% gum solution was prepared and the pH of the sample was measured using Hanna pH 211 (Microprocessor pH meter) which was calibrated with a two standard buffer solutions of pH 4.00 and 7.00. The pH measurement of the gum solution was read from the instrument.

4. Ash content (%)

2 g sample of the acacia senegal was first heated on a burner in air to remove its smoke. Then it was burned in a furnace at 550 ^{o}C until free from carbon. The ash content was expressed as a percentage ratio of the weight of the ash to the oven dry weight (FAO, 1999).

5. Acid insoluble ash (%)

The ash obtained as directed under total ash was boiled with 25 ml of 2N hydrochloric acid for 5 minutes. The insoluble matter was collected on a suitable ash less filter paper (Whatmann 41), and then washed with hot water until the filtrate was neutral. The filter-paper containing the insoluble matter was transferred to the original crucible, ignited at 800°C ± 25°, in a muffle furnace to constant weight. Allowed the residue to cool in suitable desiccators for 30 minutes, and then weighed. Acid-insoluble ash content was calculated as mg per g/ percentage of the sample powder.

6. Specific optical rotation

Optical rotation is used to determine the nature of sugars in gum arabic obtained from A. senegal variety senegal. 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 then calculated according to the relationship:

$$[\alpha]^{t}_{d} = \frac{Z \times 100}{C \times L}$$

Where

α = Specific optical rotation

Z = observed optical rotation

C = concentration of solution

L = Length of polar meter cell in decimeter

D = Sodium lamp λ = 589 nano meter (nm.).

7. Tannin content

0.1ml of aqueous Ferric chloride solution was added to 20ml of a 2% aqueous solution of the gum sample and mixture centrifuged. Absence of black precipitate or blackish coloration indicated the absence of tannin (FAO, 1999).

8. Nitrogen and protein content

Protein content analysis was carried out using the Association of Official Analytical Chemist (AOAC) approved Kjeldahl method (AOAC, 1999). A nitrogen conversion factor of 6.60 was used (Nx6.60) as suggested by (Anderson, 1986) to convert nitrogen to protein.

9. Apparent equivalent weight

The numbers of mls of 0.02N sodium hydroxide that neutralizes 10 ml of 3% gum solution represented the acid equivalent weight of gum. From which the uronic acid content, could be determined (Karamalla, 1965; Anderson et.al, 1983; Vandevelde, 1968; Jurasek. et.al, 1993).

10. Uronic acid (%)

Uronic acid percentage was determined by multiplying the molecular weight of uronic acid (194) by 100 and dividing by the apparent equivalent weight of the sample.

11. Internal energy

Internal energy was obtained by placing a clean dry crucible of known weight in a muffle furnace and temperature raised to 550°C. The contents removed, cooled in a dessicator for 30 min and weighed and ignited at 850°C for two hours, then cooled in a dessicator for 30 min and weighed.

Internal energy was determined as the percentage loss in weight after ignition of the original sample. Internal energy of *Acacia senegal* samples is the actual energy required to produce the amount of carbon when the gum is heated to 500°C to release carbon dioxide gas.

12. Volatile mater

Volatile matter of gum arabic determines the characteristics and the degree of polymerization contained in sugar compositions (arabinose, galactose and rhamnose) which exhibits strong emulsifying properties functioning as binders and stabilisers in the making of cough syrups in pharmaceutical industry (Phillips and Williams, 2001).

Volatile matter was determined as percentage ratio of the change in weight to the original sample weight according to the methods of Anderson and Ingram (1993) and Okalebo et al. (2002).

13. Sugar content

The sugars were obtained via hydrolysis by the methods described by Randal *et al*.(1989). The samples were hydrolyzed to liberate the sugar residues. The purpose of analyzing the sample by HPLC was to determine the relative concentration of each sugar residue present in the sample namely rhamnose, arabinose, galactose and glucuronic acid. Before analysis of the gum samples, calibration curves of these sugars were prepared. This calibration allowed the determination of the unknown sugar content for the gum samples. The concentration of each sugar was calculated by beak height and expressed as % of the total sugar content.

14. Intrinsic viscosity

For evaluation of rheological properties dried powder samples were dissolved using magnetic stirrer for 3 h and left overnight for full hydration and then centrifuged to remove air bubbles and insoluble particles for 10 min at 2500 rpm and 30 ^{o}C (Sanchez et al., 2002). The solution was filtered using 100 µm mesh. Relative viscosity of acacia Senegal was measured in filtered 1% aqueous solution using U-shaped viscometer (AOAC, 1990).

The viscometer was immersed in a liquid bath at 30 ^{o}C temperature The sample solution was introduced to the viscometer flowing freely, the time required for the solution to pass from the first to the second timing mark was measured, in seconds (Al-Assaf, Phillips, & Williams, 2005). The intrinsic viscosity was calculated according to the following equations:

Relative viscosity (η_{rel}) = T / To (1)

Specific viscosity (η_{sp}) = (T–To) / To = (T / To) –1= η_{rel}-1 (2)

Reduced viscosity (η_{rd}) = η_{sp} / C (3)

Intrinsic viscosity [η] = lim η_{sp}./c (4)

c → 0

Where

T: Flow time of 1% of gum arabic solution.

To: Flow time of distilled water. (All times were measured in seconds).

C: concentration of acacia senegal gum sample solution

The intrinsic viscosity was [η] was determined by extrapolation of reduced viscosity against concentrations back to zero concentration. The interception on Y – axis gives [η].

15. Total soluble fiber: Total soluble fiber was obtained by subtraction of contents of moisture, ash and protein from 100.

16. Refractive index: Refractive index of gum samples was measured in a filtered 1% aqueous solution using an Abbe refractometer.

17. Cationic compositions

The cationic compositions of ash content are used to determine the specific levels of heavy metals in quality of gum arabic (FAO, 1990, 1996).Ash from a sample of *acacia Senegal* was prepared and dissolved in concentrated sulfuric acid. The solution was used for determination of mineral content by atomic absorption spectrophotometry, except for sodium and potassium metals, which were determined by flame photometry. (AOAC, 2000). Appropriate standard solution was prepared for each metal and used by the atomic absorption spectrometer to prepare the graph for the determination of the amount of each metal from the gum solution.

Functional Properties Analysis

Functionality analysis of *Acacia senegal* gum of different forms Hand Picked Selected (HPS), cleaned, kibbled, powdered and spray dried) were carried out as follows:

1. Water Holding Capacity (WHC)

Is the ability of the material to hold water against gravity (Hansen, 1978). It was determined according to Hansen, (1978). 1g of gum was accurately weighed in a Petri-dish, then it was placed in desiccators half-filled with distilled water and incubated for certain lengths of time: 24, 48, 96, 120, and 144 hours. The Petri-dish with samples was then weighed (g/g) and finally expressed as percentage as

Follows:

$$WHC\% = \frac{\text{Weight of water} \times 100}{\text{Weight of sample}}$$

Where

WHC = Water holding capacity.

2. Emulsifying Stability

It was determined according to Kinsella, (1979). Gum arabic solution (20% concentration) was mixed with oil (sunflower oil) at a ratio of 80: 20 W/W, respectively. They were mixed using a blender for one minute at 1800 rpm. The mixture was then diluted to a ratio of 1: 1000 and it was read at λ max. 520nm using Spectrophotometer.

The second reading was taken after one hour.

Emulsifying stability (E.S.) was calculated as follows:

$$(E.S.) = \frac{\text{Reading after 1 hour}}{\text{First reading}}$$

Statistical Analysis of Data

Each sample was analyzed chemically in triplicate then averaged. Data was assessed by analysis of variance (ANOVA), the mean separation was carried out by Duncan's multiple range tests with probability of 0.05 levels.

RESULTS AND DISCUSSION

Shape and color: Table (1) illustrates the evaluation of the shape and color of the five gum Arabic samples. The Hand picked selected and cleaned consist of nodules free from contamination by plant bark, visible objects and other substances, it was in the natural form, color and size of the particles. On the other hand, the kibbled, powdered and spray dried formulations were passed through some processing steps; hence, their shape and color were changed.

Table 1: Shape and color of *Acacia senegal* samples.

***Acacia Senegal* Sample**	**Shape**	**Color**	**Ø – Diameter**
Hand picked selected (HPS)	Spheroidal tears	Pale white to orange – brown	Ø >30 mm
Cleaned	Spheroidal tears	White to Yellowish-white Flakes	10 <Ø<20mm
Kibbled	Spheroidal tears or in angular fragments	White to yellowish white	0.5< Ø<6mm
Mechanically Powdered	Powder	White to cream powder	Ø<200 µ
Spray dried	Powder	White to cream powder	Ø<100 µ

Moisture content and Solubility: Table 2 shows that moisture content and solubility of *Acacia Senegal* samples in different solvents. Results indicate that the moisture content fall between (8.91±0.97%) for spray dried gum and (13.67±0.97%) for Hand Picked Selected gum, and there were significant difference at ($p \leq 0.05$) in the level of moisture content between the five samples. The low level of moisture content for spray dried gum may be due to treatment of gum with heat during spray drying process while for Hand Picked Selected gum (raw gum) the moisture content was the highest. Also we observe that as particle size of the gum reduced during processing the moisture content also reduced. FAO food and nutrition paper specifies that loss on drying of good quality gum does not exceed 15% for granular and 10% for spray-dried material (FAO, 1999). All samples lies within international specifications. Moisture content determines the hardness of the gum. Any excess of water in medicinal plant materials will encourage microbial growth. Moisture content facilitates the solubility of hydrophilic carbohydrates and hydrophobic proteins in gum Arabic (Montenegro *et al.*, 2012).

Gum arabic is highly soluble in hot and cold water in concentration up to 50 %. The gum has the ability to produce concentrated solutions without causing an excessive increase in viscosity, because principally to the branched and compact structure and a small hydrodynamic volume (Williams et al. 1990a; Goycoolea et al. 1995; Verbeken et al. 2003). Table 2 shows that *acacia Senegal* gum is highly soluble in water, solubility range from (97.38±0.38%) for Kibbled gum and (99.12±0.38%) for spray dried gum, the difference in solubility between the five samples is insignificant at ($p \leq 0.05$). The gum has the ability to produce concentrated solutions without causing an excessive increase in viscosity, because principally to the branched and compact structure and a small hydrodynamic volume (Williams et al. 1990a; Goycoolea et al. 1995; Verbeken et al. 2003).*Acacia Senegal* gum has very low soluble in alcohol and insoluble in acetone and chloroform.

Table 2: moisture content of *Acacia Senegal* samples and solubility in different solvents.

Acacia Senegal **Sample**	**Moisture content (%)**	**Solubility in different solvents (%)**			
		Water	**Ethanol**	**Acetone**	**Chloroform**
HPS	13.67	97.64	0.05	0.00	0.00
Cleaned	13.22	97.43	0.07	0.00	0.00
Kibbled	12.56	97.38	0.09	0.00	0.00
Powdered	11.02	98.46	0.03	0.00	0.00
Spray dried	8.91	99.12	0.04	0.00	0.00
Mean	11.88	98.01	0.06	0.00	0.00
SD	1.94	0.56	0.02	--------	--------
SE (±)	0.97	0.38	0.01	--------	--------
C.V. (%)	14.60	0.69	38.47	--------	--------

pH, ash, acid insoluble ash, specific optical rotation and tannin content

Table 3 shows all gum samples were slightly acidic pH range (4.32 - 4.49) due to the presence of free carboxyl groups of D-glucuronic acid and 4-O-methyl D-glucuronic acid residues (Karamalla et al., 1998). No significant difference in pH value between the five samples, mean value of all samples was (4.40±0.03).

Also Table 3 shows that there were significance differences at ($p \leq 0.05$) for ash content, acid insoluble ash and specific optical rotation between the five samples. The lowest ash content percentage and acid insoluble ash were for spray dried gum (3.03±0.17%) and (0.12±0.03%) respectively, and the highest specific optical rotation was for spray dried gum (-32.74±1.15), which may be due to the fact that spray dried gum contains the least impurities compared with the other samples. The Joint Expert Committee for food additives (JECFA) of FAO specifies that the best quality of gum arabic must have ash content within the range of (2-4%) Optical rotation measured angle of diffraction of polarized light through the material, it is used to classify *Acacia* species. The Joint Expert Committee for food additives (JECFA) of FAO specifies that the aqueous solutions of *Acacia senegal* gums are levorotatory. The specifications state that the best quality of gum arabic must have negative optical rotation with the range of -26° to -34°.The results shown agree with mentioned specifications.

Ash content is a measure of inorganic residue remaining after removal of organic matter by burning. Total ash content is used to determine the critical levels of foreign matter, acid insoluble matter, and salts of calcium, potassium and magnesium (Montenegro *et al.*, 2012).

It was found that all samples are free from tannin. All samples lies within international specifications for pH, ash, acid insoluble ash, tannin content and specific optical rotation and comply with JECFA (1990) specification.

Table 3: pH, ash, acid insoluble ash, tannin content and specific optical rotation of Acacia Senegal samples.

***Acacia Senegal* Sample**	**pH**	**Ash content %**	**Acid insoluble ash %**	**Specific optical rotation**	**Tannin content**
HPS	4.39	3.82	0.26	-27.73	- ve
Cleaned	4.32	3.69	0.22	-27.11	- ve
Kibbled	4.37	3.85	0.25	-27.52	- ve
Powdered	4.49	3.58	0.19	-28.61	- ve
Spray dried	4.45	3.03	0.12	-32.74	- ve
Mean	4.40	3.59	0.21	-28.74	---------
SD	0.07	0.33	0.06	2.30	---------
SE (±)	0.03	0.17	0.03	1.15	---------
C.V. (%)	1.36	8.29	24.21	7.16	---------

Nitrogen, Protein, total soluble fiber apparent equivalent weight and Uronic acid

Results in table 4 indicated that the difference between the five samples of *acacia Senegal* in percentage nitrogen, protein content and total soluble fiber is insignificant at ($p \leq 0.05$), also the difference between the samples in apparent equivalent weight and uronic acid content is insignificant at ($p \leq 0.05$). These results give us an indication that processing of *acacia Senegal* gum did not affect nitrogen, protein, uronic acid and fiber content of the gum. Table 4 shows the distribution of nitrogen content of the samples fall within the range (0.27-0.39%) set out by JECFA (1990).

The acid equivalent weight and the corresponding calculated uronic acid contents are given in Table 4. The table shows that the acid equivalent weight of *acacia senegal* samples fall between 1216 and 1298 with the corresponding glucouronic acid within the range of 15.95% and 14.70% with mean values of 1254 and 15.48, respectively.

GA is an excellent source of non viscous soluble fiber (Williams *et al.*, 2000). As a hetero-polysaccharide, human aren't able to directly extract any calories from it. The results in (Table 4) showed that the mean fiber content was 82.06%. Different studies reported almost similar values for total soluble fiber for GA such as 84.1% and 82.1% for samples obtained from Kordofan and Damazin, respectively (Sabah El-Kheir *et al*., 2008).

Table 4: Nitrogen, Protein, total soluble fiber apparent equivalent weight and Uronic acid of *Acacia Senegal* samples.

***Acacia Senegal* Sample**	**Nitrogen %**	**Protein %**	**Total soluble fiber %**	**Apparent Equivalent Weight**	**Uronic acid %**
HPS	0.35	2.31	80.20	1236	15.70
Cleaned	0.35	2.31	80.78	1216	15.95
Kibbled	0.35	2.31	81.35	1248	15.54
Powdered	0.36	2.38	83.02	1270	15.28
Spray dried	0.36	2.38	84.95	1298	14.95
Mean	0.354	2.34	82.06	1254	15.48
SD	0.005	0.04	1.93	31.60	0.39
SE (±)	0.003	0.02	0.96	15.80	0.19
C.V. (%)	1.38	1.47	2.10	2.25	2.22

Refractive index, internal energy, volatile matter and intrinsic viscosity of the Acacia Senegal samples

From table 5 we can observe that there is no significant difference in refractive index, internal energy and volatile matter for the five samples at ($p \leq 0.05$).

The intrinsic viscosity of the gum samples studied Table 5 fall between 13.75 ml/g and 16.87 ml/g. There is significant difference between the five samples in intrinsic viscosity, the highest intrinsic viscosity was for spray dried sample (16.87 ml/g) and the lowest was for hand picked selected sample (13.75 ml/g), this difference may be due to presence of some impurities which cause reduction in the viscosity.

The internal energy and volatile matter in *acacia* senegal samples meets the international specifications of purity and identity (30 to 39%) and (51-65) respectively, FAO (1990).

Table 5: Refractive index, internal energy, volatile matter and intrinsic viscosity of the *Acacia Senegal* samples.

***Acacia Senegal* Sample**	**Refractive index**	**Internal energy %**	**Volatile matter %**	**Intrinsic viscosity[η] ml/g**
HPS	1.351	32.4	62.8	13.75
Cleaned	1.347	33.6	62.3	14.48
Kibbled	1.349	32.8	61.8	14.61
Powdered	1.355	33.9	63.1	15.72
Spray dried	1.354	34.1	63.9	16.87
Mean	1.351	33.4	62.8	15.09
SD	0.003	0.73	0.80	1.22
SE (±)	0.002	0.37	0.40	0.61
C.V. (%)	0.30	1.96	1.14	7.24

Cationic composition of *acacia Senegal* gum samples

Characterization of the gum samples by mineral content showed that potassium (8287-11026) (ppm) was the highest for all gum samples, followed by calcium (6328-8825), magnesium (2210-3486), iron (758-1633),sodium (145-397), copper (52-65). Other elements (Zn, Mn, Co, Ni, Cr etc) and heavy metals (e.g. Pb) were not detected by atomic absorption spectrophotometric analysis in our study.

FAO food and nutrition paper 52 includes in its definition of Gum Arabic that it consists mainly of high molecular weight polysaccharides and their calcium, magnesium and potassium salts.

Table 6 shows that calcium; magnesium, potassium, sodium, iron, and copper are the most abundant elements in all gum samples. The mean values in the table show that the major elements in *acacia senegal* samples showed the trend as follows K>Ca> Mg> Fe >Na> Cu. However, it is evident that the elemental composition is the main reason which contributes to different colors and appearance of different nodules of the same variety or even within different regions in the same nodule. Moreover, Fe and Cu are transition metals which form colored complexes, therefore they can be considered to be the main reason for coloration.

However, most elements are soil dependent; therefore their amounts are expected to increase or decrease within different regions in the same nodule.

Table 6: cationic composition of *acacia senegal* samples (ppm).

Acacia Senegal Sample	Ca	Mg	Na	K	Fe	Cu
HPS	8522	2911	145	9985	758	59
Cleaned	8825	3175	397	11026	1462	60
Kibbled	7895	3486	266	9878	1125	65
Powdered	7182	2210	312	8287	1633	52
Spray dried	6328	2711	221	8412	864	58
Mean	7750	2899	268	9518	1168	59
SD	1014	482	95	1158	376	4.7
SE (±)	507	241	47	579	188	2.3
C.V. (%)	11.71	14.89	31.60	10.88	28.77	7.08

Sugar percentage content of *acacia senegal* gum samples

Characterization of the gum samples by percentage sugar content showed that Galactose (41%-43%) was the highest for all gum samples, followed by Arabinose (24%-27%), Rhamnose (15%-17%) and glucoronic acid (15%-16%). The mean values in the table 7 show that A. senegal samples sugar showed the trend as follows Galactose > Arabinose > Rhamnose > glucoronic acid. From table 7 we can observe that there is no significant difference between the five samples at ($p \leq 0.05$) in Galactose, Arabinose, Rhamnose and glucoronic acid content. This result gives us an indication that processing of acacia Senegal gum did not affect its sugar content.

Table 7: Sugar percentage content of *acacia senegal* samples.

Acacia Senegal Sample	Galactose (%)	Arabinose (%)	Rhamnose (%)	Glucouronic acid(%)
HPS	41	26	16	16
Cleaned	42	26	15	16
Kibbled	41	27	15	16
Powdered	43	24	17	15
Spray dried	42	26	16	15
Mean	41.8	25.8	15.8	15.6
SD	0.84	1.10	0.84	0.55
SE (±)	0.42	0.55	0.42	0.27
C.V. (%)	1.8	3.80	4.74	3.14

Water holding capacity and emulsifying stability for *Acacia Senegal* samples

From table 8 that there is no significant difference between the five samples in water holding capacity and emulsifying stability at ($p \leq 0.05$). Water holding capacity for *acacia Senegal* samples range between (67.03±0.50) for cleaned sample and (69.05±0.50) for spray dried sample with a mean of (67.77±0.50). Emulsifying stability for acacia Senegal samples range between (1.005±0.005) for hand picked selected and (1.032±0.005) for spray dried sample with a mean of (1.018±0.005).

Water-holding capacity (WHC) is the ability of the material to hold water against gravity. The water holding capacity of gum is the ability to hold water and does not only depend on the functional group of carbohydrate that are hydrophilic but also on the protein present in the gum, since they also contain functional groups that are able to bind with water molecule. 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. The gum from *Acacia senegal* has a functional ability to act as emulsifier that stabilizes oil-in-water emulsion (Yokoyama *et al.*, 1988; Randall *et al*., 1988).

Table 8: Water holding capacity and emulsifying stability for *Acacia Senegal* samples.

***Acacia Senegal* Sample**	**Water holding capacity (WHC)%**	**Emulsifying stability**
HPS	66.85	1.005
Cleaned	67.03	1.018
Kibbled	67.28	1.012
Powdered	68.65	1.023
Spray dried	69.05	1.032
Mean	67.77	1.018
SD	1.01	0.013
SE (±)	0.50	0.005
C.V. (%)	1.32	0.91

CONCLUSION

This study showed that processing of acacia Senegal gum affect moisture content, ash content, acid soluble ash content, specific optical rotation and intrinsic viscosity. These effects may be due to the fact that processing help in purification of the gum from impurities that may be found in unprocessed gum. Also this study showed that processing of acacia Senegal gum did not affect water solubility, pH, nitrogen content, protein content, total soluble fiber, apparent equivalent weight, uronic acid content, refractive index, internal energy, volatile matter and sugar content of this gum. The functional properties of acacia Senegal gum like water holding capacity and emulsification properties also not affected by gum processing. From these results we can expect that processing of acacia Senegal gum did not affect acacia Senegal gum chemical composition and functional groups that found in this gum. So processing improves *acacia Senegal* gum purity without affecting physicochemical and functional properties of this gum.

All *Acacia Senegal* gum samples studied meet the specifications given by The Joint Expert Committee for Food Additives for Gum Arabic.

The spray dried grade is the most pure grade and recommended to be used in food and pharmaceutical industry.

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