PHYSICOCHEMICAL AND FUNCTIONAL PROPERTIES OF THE GUM ARABIC FROM *ACACIA SENEGAL*

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Abstract
Different studies reported variation on the physicochemicalproperties of Acacia Senegal var. Senegal gum Arabic exudates due to different factors including soil type, condition of the plant and climatic conditions. This work was performed on gum Arabic sampled from one area within the gum Arabic belt in Sudan. The aim was to study the physicochemical properties of this single sample. The data was analyzed comparatively to previously published records (1968-2016) from different areas in the gum belt, Sudan. The main physicochemical and functional features of the exudates gum Arabic were determined using different methods. The data obtained indicate the following values: moisture (14.5%), ash (2.5%), protein (2.2%), nitrogen (0.34%), viscosity (15.2mL/g) and pH (4.34). The fat content and nitrogen free extract were also analyzed and the values obtained were 0.05%, and 80.75%, respectively. The present data were compared with that published and is evidence that the properties: ash, protein and nitrogen were stable to a great extent regardless of factors such as area of collection and climatic condition within the gum belt. Moisture content showed less constancy and might be affected mainly by climatic conditions during exudation or storage type. Viscosity and pH revealed immense variations which can be attributed to variable preparation procedures followed such the concentration and temperature of gum solutions, and laboratory conditions.

Keywords: comparative data, specifications, proximate analysis.

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1. INTRODUCTION

Gums are natural exudates from different plant parts but mainly the trunk. It comes out from area between bark and the cambial zone when stem injured incidentally or intentionally by tapping wounds, fungal and beetle infestations. The most widely used gum is that obtained from *Acacia senegal var. senegal* (L.) Willd. well known as gum acacia or gum Arabic commercially exist as early as 4000 B.C. Gum Arabic (GA) is defined by FAO-JECFA as “a dried exudation obtained from the stems and branches of *A. senegal* (L. Willdenow) or closely related species of *Acacia* (family Leguminosae)” (FAO, 1990). Accordingly, FAO-JECFA set a number of specifications of the quality parameters for GA based on Kordofan gums (Table 1).

For commercial production of GA, the duct of the inner bark of *A. senegal* usually tapped when the trees are stressed during dry season. Gum nodules appearance in 3-8 weeks from the broken scars. Annual yields stand at 188-2856 g for young trees and 379-6754 g for older trees (7-15 years).

GA obtained from *A. senegal* has the greatest commercial value and is recognized as the best in quality. The composition of GA is effected mainly by the location, tree age, season of exudation, storage type and the genetic factor (Williams *et al.*, 2000; Montenegro *et al.*, 2012).Trees stressed due poor nutrition, lack of moisture and high temperature exudate excellent quality and higher quantity of gum. Although *A. senegal*, grown in “gum gardens” of Kordofan State, Sudan, is the principal source of GA with over 90% of the world’s supply, Chad and Nigeria have their share (Williams *et al.*, 2000). Even so, the grades of GA obtained from *A. senegal* vary considerably in quality (Karamalla, *et al*., 1998). The properties of GA can be affected by contamination and impurities, therefore, care must be taken during production and transporting to insure clean products which may lower its grade. The best commercial grades of GA are highly dissolves in cold and hot water i.e. up to 50% W/W, forming a colorless or pale yellow, tasteless solution with acidic properties (pH ≈4.5) (Karamalla, 1999; Montenegro *et al.*, 2012; Daoub *et al.*, 2016). This is one of important property that distinguishes gum from other exudates such as resins, latexes and other hydrophobic gums (Yusuf, 2011). In addition, a high-quality GA has could forms solutions over a wide range of concentrations without becoming viscous until high concentration is made (Siddig, 2003; Daoub *et al.*, 2016). The combination of high water-solubility and low viscosity makes GA excellent emulsifier, stabilizer, thickener and suspender. These good characteristics are what formulate the standard and quality of a batch of GA and determine its use in food, pharmaceuticals and cosmetic industries. Whereas, the lower grades of gum are used in other important industries such as printing, textiles, lithography, paints, production of explosives, and anti-corrosive coating for metals (Lelon *et al.*, 2010). On the other hand, these characteristics are used to distinguish gum of *A. senegal* from the other commercially important gums of closely related acacias such *A. polyacantha* and *A. seyal*.

To identify the quality and to differentiate between various types of gums; several properties must be analyzed. The most important chemical components include total ash, nitrogen content, total protein, moisture content, tannins and analysis of the ratio of neutral sugars. Likewise, the most important functional-physical properties include water solubility, optical rotation, intrinsic viscosity, equivalent weight and molecular mass (Daoub *et al.*, 2016). Table 2 summarizes the general information available to date on physiochemical properties of GA from *A. senegal* for comparative purpose.

The aim of this study, therefore, was to perform proximate physiochemical and functional analysis of gum Arabic collected from *Acacia senegal* var. *senegal* on specific area in Sudan to standardize specification and compared with prior data.

Table 1: International specifications of some 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

Source: (FAO, 1990)

2. MATERIALS AND METHODS

2.1. Collection and preparation of sample

The gum Arabic was obtained from Abkrusholla city, South Kordofan State, west Sudan in October 2016. The collected GA nodules were cleaned by hand to remove any sand, dust and bark that may found. Then gum was well mixed and crunched using local hammer mill into ground powder and stored in plastic containers till used. All the chemicals and reagents used in this study were of analytical grade

2.2. General physicochemical analysis

Physical and chemical properties of coarse powdered gum were determined according to the Association of Official Analytical Chemist (AOAC, 1990). The various methods used to determine the physicochemical properties were reported.

Moisture and ash determination

Total moisture content (MC) was determined as follow. Accurately weighed one gram of sample was placed in a crucible. Then heated in an air dry oven at 105ºC and left overnight. After cooling under at room temperature, the crucible was re-weighed and the process was repeated till constant weighed was obtained, accordingly:

$MC\% = [(w_2-w_1)-(w_3-w_1)]/ [(w_2-w_1)] \times 100.$

where: w_1= weight of empty crucible, w_2= weight of crucible + sample, w_3= weight of crucible + dry sample.

To determine ash content, one gram of gum sample was weighed in crucible and placed in muffle furnace at 550ºC for 3 h until white to grey ash was obtained, then:

Ash content% = $(w_2\text{-}w_1)/ w_s \times 100$

Where: w_1= weight of empty crucible, w_2= weight of crucible with ash, w_s=weight of sample.

Nitrogen and crude protein

Nitrogen was determined by a semi-micro Kjeldahl method (AOAC, 1990). After titration the nitrogen percentage was calculated as:

N% = $(V \times N \times 14)/w_s \times 100$

where V = volume of HCl, N = normality of HCl, 14 = atomic mass of nitrogen.

Crude protein (CP) is based on a laboratory nitrogen analysis, from which the total protein in gum sample can be obtained. Therefore, CP content was calculated by multiplying the amount of nitrogen with the nitrogen conversion factor (NCF) of 6.43 (Anderson and McDougall, 1987).

Crude fiber

Determination of crude fiber (CF) content was achieved using glacial acetic acid and nitric acid solution. One gram of sample was boiled in the solutions for 40 min and filtrated. The mix then was put in oven till ash obtained. The calculation was made as:

CF% = $(w_m – w_a) /w_s \times 100$

where w_m = weight of moisture, w_a= weight of ash.

Viscosity and pH determination

Viscosity was measured using U-tube viscometer with the flow time for 1% aqueous solution of sample at room temperature (40ºC). The relative viscosity (Ƞr) was then calculated as:

Ƞr = $(T - T_0)/ (T_0)$

where: T= flow time of sample solution expressed in seconds, T_0 = flow time of solvent (distilled water) expressed in second.

For measuring pH, two grams of powdered gum were dissolved in 50 mL of distilled water, and then suspended in glass for 2 h. The clear solution was used to determine the pH.

Fat content and nitrogen free extract

The fat or ether extract was determined using Soxhlet method. One gram of sample was extracted with 50 mL petroleum spirit for 8 h. The ether extract was weighed and fat content (FC) as percentage:

FC% = $(w_2\text{-}w_1) /w_s \times 100$

where: w_1= weight of empty flask, w_2= weight of flask and oil.

The calculation of nitrogen-free extract (NFE) was made as:

NFE% = % DM – (% FC + % CP + % ash + CF)

where: DM = dry matter% = 100% - MC%.

2. 3. Statistical analysis

A completely randomized design was used in the experimentation. Samples were analyzed in triplicate and then averaged. Statistical analysis of variance (ANOVA) was carried out using Genstat Statistical Software Edition 10.3 (VSN International Ltd., 2011). The ANOVA was performed in one-way and the means were separated using Duncan's Multiple Range Test (DMRT) at the 5% level.

3. RESULTS AND DISCUSSION

General physicochemical properties of GA

GA is a natural product complex mixture of hydrophilic carbohydrate and hydrophobic protein components (FAO, 1990). Hydrophobic protein component serves as an emulsifier while hydrophilic carbohydrate component inhibits aggregation of molecules (Lelon, 2010). Addition of GA to water leads to lowering of the surface tension. GA physicochemical responses can be handled depending on the hydrophilic and hydrophobic interactions. The functional properties of GA are linked to its structure, which determines the degree of solubility, viscosity, emulsion, etc. (Montenegro *et al.*, 2012). The results on physical and chemical properties of GA studied along with preceding data were given in Table 3. The physicochemical features of GA under study can be discussed from a more representative viewpoint using Table 2.

Viscosity and pH

The results showed that the viscosity for GA was found to be 15.2 mL/g (Table 3). Most of previous studies reported values in a range of 14-16 with average of 16.9 (Table 2). Idris

(1989) measured the viscosity of GA samples obtained from *A. senegal* trees of different ages and concluded that it ranged from 7.2 to 14.2 cm^3/g. Jurasek *et al.* (1993) analyzed 18 specimens of GA and found their viscosity to range from 13.4 to 23 mL/g. Siddig (1996) analyzed about 94 GA samples for intrinsic viscosity and reported the mean value of 16.44 mL/g. These large variations can be attributed to different factor such as storage period, preparation method of the gum solution, concentration of the resultant gum solution and room temperature during preparation (Karamalla *et al.*, 1998). The amount of insoluble gel greatly influences the degree of viscosity (Mhinzi, 2003). Idris (1989) concluded that the age of *A. Senegal* tree affected the viscosity of GA solution. Anderson *et al.* (1968) determine the ages 10-15 years of trees to be produced gums with higher viscosity, while the oldest and youngest trees studied gave gum of low viscosity. Montenegro*et al*. (2012) stated that solutions containing less than 10% of GA have a low viscosity. Generally, to obtain higher viscosity with GA the concentration need to be up to 40-50% (Siddig, 2003). Accordingly, Karamalla, (1999) declared that, the wide variations in values of average viscosity indicating that such parameter cannot be used as qualifying indices. Instead, El Amin *et al.*, (2013) suggested classification for GA according to viscosity into high (80-85 cps), medium (69-70 cps) and low (<60 cps) viscosity. Ameh *et al.* (2010) stated that the increase in viscosity of the gum is a result of raising the pH and the reduction in viscosity is due to increasing temperature. In addition, it can be clearly noticed from Table (2) that each study reported a different value for pH of studied gum solution (range: 3.9-5.54). In connection, the pH of GA aqueous solution, in the present study, was found to be 4.34 (Table 3). The variable pH values reported might be result of inconsistency in temperature of the gum solution or the surrounding condition. El Amin *et al.*, (2013) reported that there were no significant effects of soil type or rainfall level (source effects) in the pH of GA samples analyzed. However, Tahir *et al.* (2007) proved that, the age of both nodule and the donor tree were significantly affected the pH of GA under study.

Table (2): Comparative analytical data (1987-2016) on characteristics of GA samples collected from *A. senegal* in Sudan

Reference	MC (%)	Ash (%)	NC (%)	PC (%)	η	pH
Anderson *et al.* 1968	13.1	3.75	0.37	2.38[a]	30.0	4.58
Anderson & McDougall, 1987	5.0	3.6	0.34	2.19	15.0	n.d
Idris *et al.*, 1998	14.12[b]	n.d	0.33[b]	2.1[b]	14.25[b]	n.d
Karamalla*et al.*, 1998	10.25	3.75	0.33	2.12[a]	16.4	4.7
Siddig, 2003	12.7[b]	3.8[b]	0.34[b]	n.d	14.2[b]	4.5[b]
Mohammed Kheir, 2005	8.87	3.64	0.38	2.54	15.9	4.22
Tahir *et al.*, 2007	10.75[b]	1.9[b]	0.39[b]	2.52[a]	n.d	5.54
Elmanan*et al.*, 2008	12.7[b]	3.25[b]	0.31[b]	2.1[b]	16.3[b]	4.38[b]
Sabah El-Kheir*et al.*, 2008	10.6[b]	3.4	n.d	2.35[b]	19.6[b]	3.9
Khalil *et al.*, 2011	8.7	2.8	0.35	2.25[a]	n.d	n.d
Ali *et al.*, 2012	12.91[b]	4.45[b]	0.34[b]	2.19[a]	14.2[b]	4.41[b]
Bashir and Osman, 2013	10.11	3.7	0.28	1.85	17	4.47
Ibrahim *et al.*, 2013	13.49	3.27	0.35	2.31	14.61	n.d
Daoub*et al.*, 2016	9.76	3.4	0.33	2.16	n.d	4.94
Osman, 2016	8.4	3.2	0.41[b]	2.58[b]	15.3	4.6
Siddig, 2016	12.1	3.2	0.3	1.93[a]	n.d	4.3
Mean	10.85	3.41	0.34	2.24	16.9	4.55
Range	5-14.12	1.9-4.45	0.28-0.41	1.85-2.58	30-14.2	3.9-5.54
Standard error	0.60	0.14	0.01	0.05	0.94	0.09

MC: moisture content, NC: nitrogen, PC: protein, η: viscosity, n.d: not determined.
[a]Value calculated by the author using NCF of 6.43; [b] Average calculated by the author.

Moisture and ash determination

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). The present study showed that the moisture content of GA was found to be 14.5 % (Table 3). This value was within range 8.1-14.7% that determined by Siddig (1996) and range of 13-15% that of FAO (1990) specifications (Table 1). However, Table 2 endow with a range of 5.0-14.12% according to previous data on AG collected from different areas in Sudan. Tahir *et al.* (2007) attributed the variations in moisture content between GA samples collected within the Sudan gum belt, to the nodule age; e.g., storage affect. As *A. Senegal* tree is very variable botanically; each tree tends to produce a unique form of gum, the different nodules from a single tree are remarkably similar to each other in comparison to those from other trees (Anderson *et al.*, 1968). Variable values were also reported on moisture content of GA collected from different countries such as 13.2-15.6% in Tanzania (Mhinzi, 2003), 15-14.9% in Kenya (Lelon, 2010), 13.9% in Nigeria (Gashua *et al.*, 2016), 12.6-13.4 % in Ethiopia (Yebeyen and Haile, 2017).

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). The result showed that the average ash content was 2.5 % (Table 3). This result was among the least values presented in Table 3, however, it was within the 2-4% range specified by FAO (1990) (Table 1). Likewise, almost all values reported by previous studies reported herein (average: 3.41; Table 2) were within this range. Anderson *et al.* (1968) found that, GA samples of heavy soil has an average ash content of 3.5%, while 3.3% was for samples from sandy soil. Similar values of ash content were also reported on several studies in different countries such as 3.91 in Tanzania (Mhinzi, 2003), 2.94-3.16% in Kenya (Lelon, 2010) and 3.1% in Nigeria (Gashua *et al.*, 2016).

Nitrogen and crude protein

The protein fraction is responsible for the emulsification properties of the gum. Nitrogen content in gum arabic determines the number of amino acid compositions with the range of 0.26 to 0.39% (FAO, 1990). In the present study, the value of nitrogen contents was found to be 0.34%; hence calculated protein value was 2.2% (Table 3). These results were same with that reported by Anderson and McDougall (1987) where protein was 2.19% and nitrogen 0.34% (Table 2). Almost all values from different studies on GA samples from Sudan (Table 2) reported similar values for protein and nitrogen. The value of nitrogen (0.33%) reported by Karamalla *et al.* (1998) was an average of samples collected between 1960 and 1995 and appeared that all values during this period was invariable. Other data on GA samples from Sudan reported similar values for protein and nitrogen were such as 2.14- 2.16% (Osman, 1998) and 0.27-0.38% nitrogen (Jurasak *et al.*, 1993). The slight disparity might be attributed to the area of collection as some were obtained from western and other from eastern parts of the gum belt. Williams *et al.* (2000) determine protein content of sample collected from eastern Sudan was higher (2.4) than (2.0) from Kordofan (West). Similarly, Idris *et al.*, (1998) reported that samples from eastern Sudan were higher in protein content (2.3) than (1.9) from western Sudan. The assumption is that, the protein content of fresh samples was constant irrespective to the age of the tree.

In contrast, significant effects of tree age on nitrogen content of GA were reported (Tahir *et al.*, 2007). That GA collected from youngest trees (5-10 years) has higher nitrogen content than that from older trees (15-20 years).

Table 3: Physicochemical properties of GA (*A. senegal*)

Property	Value
Moisture content (%)	14.5
Ash (%)	2.5
Nitrogen (%)	0.34
Protein (%)	2.2*
Crude fiber (%)	81.9
Fat content (%)	0.05
Nitrogen free extract (%)	80.75
Viscosity	15.2
pH	4.34

*Calculated using NCF of 6.43.

Fiber, reducing sugars, NFE and fat contents

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 (Table 3) showed that the fiber content was 81.9%. 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). Variable values of fiber content were also reported for samples of *A. senegal* gums collected from Nigeria as 80.41% Yusuf (2011) and 82.05% (Gashua *et al.*, 2016). Lower values of fiber were reported other tree species such as 78.4% in the gum of *Albizia furriguinea* (Amehet *al.*, 2010) and only 6.15% in gum karaya (*Sterculia setigera*) (Adelakun *et al.*, 2014). Nitrogen-free extract (NFE) hypothetically represents the total soluble carbohydrate in gum which includes sugars, starch, pentosans and uronic acids. In this study the NFE was found to be 80.75%. Fats (ether extract) is part of non-nitrogenous substances. The result on analysis GA showed that the fat content was 0.05%. Several studies on other gums reported different values for crude fat. El-Daw (1998) determined fat content in guar gum (*Cyamopsis tetragonolabous*) to be 0.17%. Gum karaya (*Sterculia setigera*) reported to have high fat content up to 26.03% (Adelakun *et al.*, 2014).

The variations on GA physicochemical parameters reported currently and in published data can be attributed to the origins of samples within gum belt of Sudan. That, the gum belt in Sudan extends over a wide area across the country from west to east. This wide area exhibits diverse environmental conditions including sandy soil in the west and clay soil in the east, and dry low rainfall savannah in the north and high rainfall savannah in the south. These diverse location conditions affected the physicochemical features of GA due to the influences on trees growth and the prevailing weather during exudation and harvesting. Anderson *et al.* (1968) stated that, according to experimental and technological observations, the GA manufacturers made some restrictions such as purchases from a certain origin and declining a current season's gums, preferring that stored in the Sudan since the previous season.

4. CONCLUSION

It can be concluded that nitrogen and hence protein and ach content showed almost similar values regardless the source of gums confirmed it use as quality control. Moisture content and viscosity showed less similarity and can be clustered into 4-5 groups dependent on the values. The viscosity depends on the origin of the gum, the electrolyte content, the pH level, and solution preparation procedure. The factor of the gum origin includes the age of the trees, climatic conditions and soil environment. Therefore, specification on physiochemical properties must be provided to gum Arabic (from *A. senegal* var. *senegal*) according to soil type, geographical differences and climatic conditions, i.e.: location. The pH values showed irrelative to each other and, therefore, not functional.

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