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Physicochemical Properties of Kakamut Gum (*Acacia polyacantha*) and Hashab Gum (*Acacia senegal*): A Comparative Analysis

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Abstract: The physicochemical properties of the natural Gum are very important in determining their commercial value and their use. Herein, the present study aims to identify differences in physicochemical properties of Kakamut Gum (*Acacia polyacntha*) and Hashab Gum (*Acacia Senegal*). Samples of Gums were collected as follows: Kakamut Gum from Um fakarin forest and Hashab Gum from Eldemokeya forest, North Kordofan State 2008 – 2009. The two samples were subjected to laboratory analyzed in Warm Seas Agro Business, Elobeid Agricultural Research Station, and Sudanese Standards and Metrology Organization. The study revealed that there were significant differences ($p < 0.01$) in moisture (dry matter) and optical rotation. Also, significant differences ($p < 0.05$) were found in the percentage of ash content and viscosity. However, there were no significant differences found in the percentage of the crude fiber, nitrogen (protein), pH, and purity between the two samples. The results obtained demonstrate clearly the physical and chemical characteristics of the two Gums samples and also, throw lights on their nutritional purposes. As well as the study of the physicochemical properties of Kakamut Gum and compare it with Hashab Gum, proved the potential contribution of the Kakamut tree (*Acacia Polyacantha*) in the Gum production and not depend solely on the Gum produced from the Hashab tree (*Acacia Senegal*).

Keywords: *Acacia Senegal*, *Acacia polyacntha*, Physicochemical Properties, Gum

1. Introduction

Previously Food and Agriculture Organization of the United Nations (FAO), identify Gum Arabic as a secretion or dry natural butting from the branches of Hashab Gum (*Acacia Senegal*) or any other tree related to it, for instance, the Legume Family (Fabaceae) [1]. Recent studies revealed that, Gum Arabic is a secretion secreted by *Acacia Senegal*, *Acacia Polyacantha*, or *Acacia Nilotica* in the form of (sap) [2]. After natural or physical damage in the form of lacerations or wounds to the branches of the above-mentioned trees, the watery juice that passes out through the tissue of the tree (sap), stick together and gradually hardened into pellets [3]. The pellets collected are dried and sorted according to the quality, in order to enhance its market premium. The Gum is made up mostly of sugar (polysaccharides) with high molecular weight and salts such as, Calcium, Magnesium, and Potassium based salts, which when hydrolyzed produces Arabinose, Galactose, Rhamnose, and D-Galacturonic acid [4].

Kakamut Gum (*Acacia Polyacantha*) is defined as a secretion obtained from Kakamut tree locally known as Umsinina tree and usually collected naturally without using any tools [5]. The average length of this tree is about 20 meters and a diameter of 70 cm. It has intricate bark and double echinoderms. The bark is yellow and has brown peels with black knots at the base of the leaves [6]. The length of the leaves is approximately 25 cm. [7]. Chemically Kakamut Gum consists of high molecular weights polysaccharides and, Sodium, Iron, Magnesium, Calcium, and Potassium based salts [8]. It is considered as an important commodity capable of augmenting the production and supply of Gum Arabic [9]. therefore, availability of Kakamut Gum will enhance sustainable production of Gum in Sudan and beyond, thereby reducing the scarcity its [10].

Hashab trees (*Acacia Senegal*) which produces Gum Arabic grow in a belt called Gum Arabic belt [11]. This belt extends from Mauritania, Mali, and Senegal in the west to Burkina Faso, Niger, and parts of northern of Nigeria, Chad, Sudan, Eritrea, Ethiopia and Somalia in the east and parts of the north of Uganda, and Kenya [12]. these countries are the main exporters of Gum Arabic, but the quantity that is exported varies from one country to another [13]. Sudan is considered one of the largest producers and exporters of Gum Arabic because the greater portion of the Gum Arabic belt is located in Sudanese territory. Sudan alone produce about 80% of Gum Arabic in the world [14]. The length of the Hashab tree is about 8 meters [15]. Kakamut and Hashab trees are help to maintain balanced in the environment by increasing atmospheric nitrogen content and also improve soil fertility through nitrogen fixing, thereby increasing crops yield or production [16].

In recent times, the production of Gum Arabic in Sudan is rapidly deteriorating due to the frequent droughts, smuggling, bush fires, pests, and desertification [17]. These factors may not only affect the yield of Gum Arabic but also, the physiochemical properties could be affected and eventually jeopardized the quality of Gum Arabic. This work was aimed to study the physicochemical properties of Kakamut Gum and compare it with Hashab Gum, recognizing the potential contribution of the Kakamut tree (*Acacia Polyacantha*) in the Gum production.

2. Materials and Methods

2.1. Materials

Samples of the Gums (Kakamut (*Acacia Polyacantha*) and Hashab (*Acacia Senegal*)) were collected as follow: Kakamut Gum from Um fakarin forest and Hashab Gum from Eldemokeya forest, North Kordofan State- Sudan, the Gums samples were collected during the season 2008 – 2009 and identified by Dr. Idris Musa Adam at Agricultural Research Corporation (ARC), Kadugli Research Station, Kadugli, Sudan.

Acetic acid (CH_3COOH), Nitric acid (HNO_3), Trichloroacetic acid ($C_2HCl_3O_2$), Sulfuric acid (H_2SO_4), Cupric sulfate ($CuSO_4$), Potassium sulfate (K_2SO_4), Sodium sulfate (Na_2SO_4), Sodium hydroxide (NaOH), Boric acid (H_3BO_3), and Hydrochloric acid (HCl) were purchased from Sigma Chemical Co. (St. Louis, MO, USA). All reagents and chemicals used were of analytical grade.

2.2. Samples Preparation

Gum nodules collected from *Acacia Polyacantha* and *Acacia Senegal* trees were dried at room temperature and thoroughly cleaned to remove the bark impurities, sand, and dust. The cleaned Gum was then grinded using a mortar and pestle, sieved through a sieve No. 16 and kept in a labeled container for analysis.

i. Determination of the moisture content

The determination was conducted according to (FAO, 1990) [18]. 2g of Kakamut Gum and Hashab Gum samples were placed in the crucible with a known weight. The crucible with the sample were placed in an oven at 105°C for 24h to dry the sample then cooled in a desiccator and reweighted. The percentage was calculated as follow:

$$MC\% = \frac{W1-W2}{W0} \times 100 \quad (1)$$

Where MC%: the percentage of the moisture content, W1: the weight of the crucible + sample before drying, W2: the weight of the crucible + sample after drying, and W0: the weight of the sample.

ii. Determination of the dry matter

Since the sample represents the percentage, it is calculated as follow:

$$DM\% = 100 - MC\% \quad (2)$$

Where DM%: the percentage of the dry matter, MC%: the percentage of the moisture content.

iii. Ash determination

The determination was conducted according to (FAO, 1990) [19]. 2g of the sample were placed in the crucible with a known weight. The crucible with the sample were placed in a high temperature muffle-furnace at 550°C for 3 h, then cooled in a desiccator and reweighted. The percentage was calculated as follow:

$$AC\% = \frac{W1-W2}{W0} \times 100 \quad (3)$$

Where AC%: the percentage of the ash content, W1: the weight of the crucible + sample before burning, W2: the weight of the crucible + sample after burning, and W0: the weight of the sample.

iv. pH measurement

The pH was determined using a Hanna (ROMANIA) pH 211 microprocessor pH meter for 1.0% aqueous solution at room temperature.

v. Determination of the optical rotation

The optical rotation was determined according to (FAO, 1991) [20]. 125g of the sample were taken and dissolved in 500 mL ddH_2O using Magnetic stirrer and from this sample we measured the Brix and multiply the result by two in order to determine the volume of the water which will be used. 2 mLs of the samples were added to the volume of the water which we determined using the Brix result. The resulting solusion was then redistributed by shaking and turning upside-down several times until homogeneity was achieved at a concentration of 1.0%. The optical activity was directly measured using an automatic polarimeter AA-10R. All the experiments were performed in triplicate and the optical rotation for the Gum solution was calculated as follow:

$$[\propto]_D^t = \frac{\gamma \times 100}{C \times L} \quad (4)$$

Where ∝: The optical rotation, D: the wavelength of a sodium lamp, t: room temperature (25°C), γ: the polarimeter result, C: concentration of solution (1.0%), and L: length of polarimeter tube (1 dcm).

vi. Determination of viscosity

25g of the sample were taken and dissolved in 100 mL ddH_2O (25%) at the room temperature using Spendlil-2 speed 100 rpm. Viscosity of the solution was determined using U-tube viscometer (type Volac/BS.UC, serial No. 1094).

vii. Determination of purity

1g of the sample was dissolved in 100 mL ddH_2O. The solution was filted with the aid of a filter paper placed in an oven for 1 h. After filtration, the solution was cooled in a desiccator and weighed. As described above, the sample was filtered again and placed in an oven, cooled in a desiccator and reweighed. The difference in weight between the two samples was calculated and represent the proportion of the insoluble material in the sample. The percentage purity was calculated as follow:

$$P\% = 100 - ISM\% \quad (5)$$

Where P%: the percentage purity, and ISM%: the percentage insoluble material.

viii. Determination of the crude fiber

0.5g of the sample was placed in the digestion flask (250 mL) and was 50 mL of a solution containing Acetic acid, Nitric acid, Trichloroacetic acid and ddH_2O added. The digestion flask was placed in a digest crude fiber device for 40 minuts, and contents filtered through a filter paper. The resulting mixture was thoroughly washed by ddH_2O in order to remove any trace of the acid. With the filter paper fixed in a crucible and placed in an oven, the mixture of solutions was filtered at 105 ℃ for 24 h, cooled by a desiccator and weighed. Further, the crucible with the filter paper were placed in a high temperature muffle-furnace at 550 °C for 4 h in order to burn an organic materials, followed by cooling in a desiccator and reweighed. The percentage of the crude fiber was calculated as follow:

$$CF\% = \frac{DM^* - (A+F)}{WS \times \frac{DM}{100}} \times 100 \quad (6)$$

Where CF%: percentage of crude fiber, DM^*: weight of crucible, fiber, and the filter paper after drying, A: weight of crucible, fiber, and the filter paper after burning, F: weight of filter paper, WS: weight of sample, and DM: weight of dry matter.

ix. Determination of the nitrogen and protein contents

2g of the sample were weighted, placed in the khjeldahal digestion flask and 200 mL of H_2SO_4 with 3g Catalyst ($CuSO_4$ + K_2SO_4) added with several pieces of glass to prevent eruption. We put the khjeldahal digestion flask in the digestive system at quiet temperature in the beginning (40°C) in order to avoid the foaming. The temperature was then increased to 80°C to ease digestion. The digestive process ends when the solution completely becomes clear. The khjeldahal digestion flask is then left to cool at room temperature. 200 mL ddH_2O, 25 mL Na_2SO_4, and 75 mL NaOH were added, was further the khjeldahal digestion flask placed in the distillation unit and placed in another Erlenmeyer flask about 25 mL H_3BO_3. When the solution in the khjedahal digestion flask was heated, ammonia was librated from $(NH_4)_2SO_4$ due to the reaction between $(NH_4)_2SO_4$ and NaOH. Subsequently ammonia was condensed by cold water and collected in the form of droplets in Boric acid solution. The distillation process was continued until Boric acid color turn from pink to light green, and titrated against 0.01 N HCl. The percentage of the nitrogen and protein were calculated as follow (7, 8) respectively.

$$N\% = \frac{T \times N \times 0.014}{WS \times \frac{DM}{100}} \times 100 \quad (7)$$

$$PC\% = N\% \times 6.6 \quad (8)$$

Where N%: percentage of nitrogen, T: mls of HCl that neutralized the sample distillate, N: Normality of HCl titrate (0.01), WS: weight of the sample, and DM: weight of dry matter. percentage of protein content (PC%) was determined by multiplying nitrogen percent by factor 6.6 [21].

2.3. Statistical Analysis

All experiments were conducted in triplicate. Data are presented as mean ± standard deviation (SD). Statistical analysis was performed with SPSS version 17.0 software and GraphPad Prism version 5.0 software. Statistical significant differences in phsiochemical properties between the two samples were determined using independent-samples t-test. The differences were considered significant at $*p < 0.05$ and $**p < 0.01$.

3. Results

Table 1. *Physical properties of Acacia Polyacantha, and Acacia Senegal.*

Species	Purity (%)	Viscosity (mL/g)	Optical rotation (°)
Acacia Polyacantha	99.98	113.06	-12.02
Acacia Senegal	99.92	89.09	-28.06
P value	ns	*	**

ns: not significant, $*p < 0.05$ and $**p < 0.01$.

Table 2. *Chemical properties of Acacia Polyacantha, and Acacia Senegal.*

Species	Moisture (%)	Dry material (%)	Ash (%)	Crude fiber (%)	Nitrogen (%)	Protein (%)	pH
Acacia Polyacantha	8.08	91.92	2.02	3.44	0.27	1.78	4.55
Acacia Senegal	10.07	89.03	3.02	3.42	0.20	1.32	4.42
P value	**	**	*	ns	ns	ns	ns

ns: not significant, *$p < 0.05$ and **$p < 0.01$.

Following extraction and laboratory analysis of Kakamut Gum and Hashab Gum samples, the data obtained showed a significant difference ($p < 0.01$) in the moisture content, dry matter and optical rotation. Significant difference ($p < 0.05$) was also observed in the ash content and viscosity between Kakamut Gum and Hashab Gum samples. However, the percentage crude fiber, nitrogen, protein, pH, and purity between the two Kakamut Gum and Hashab Gum samples were comparable. The Kakamut Gum was found to be higher than the Hashab Gum in terms of the dry material, crude fiber, nitrogen, protein, pH, purity, viscosity, and optical rotation (Tables 1, 2). The moisture and ash content in the Hashab Gum was higher than Kakamut Gum (Tables 1, 2).

4. Discussion

In spite of the fact that there are more than 1100 types of *Acacias* found in the tropics and subtropics of the world, most commercial Gum Arabic is produced from *Acacia senegal* locally known as Hashab Gum in the Sudan and as Kordofan Gum in the world [22]. Moisture content analysis is a basic part of material quality and basically an element of quality control in most production and research centers. Moisture content control greatly impacts the physical properties and product quality of about all substances and materials at all phases of its preparation till final product existence [23]. The percentage of the moisture content of Kakamut and Hashab Gums as mentioned in the results are 8.08 and 10.07% the difference might be due to the period of storage method which was used. The moisture content for Kakamut and Hashab Gums are fairly similar to the value recorded by Sabah Elkheir *et al.* [24], Siddig [25], Abdelsalam [10], and Omer [26] for *Acaci*a Senegal, and Ademoh and Abdullahi [24, 27] for *combretum* from Nigeria. Ash content commonly comprises mainly of (carbonates, phosphates, silicates and silica) and has been reported to be an essential property. It is considered as a purity parameter in Gums. Most of the time the total ash content is within a characteristic narrow range and can be a helpful characterization tool [28-30]. However, the percentage of the ash content obtained in the present study ranges between (2.02– 3.02%) for Kakamut and Hashab Gums respectively. Provided that the percentage of the ash content does not exceed 4% for all Gums [31]. Results obtained were lower if compared to the value within the range 3.06-3.67% reported by Siddig [25] for *A. sensgal* gum, and lower if compared to the value of 2.9% obtained by Abdelsalam [10] and Omer [26] for *A. polyacantha* gum.

Dry matter is what remains after the greater part of the water is evaporated out of Gum. Dry matter is an indicator of the amount of nutrients that are accessible to utilize [32]. The result demonstrates that the percentage of dry matter of Kakamut and Hashab Gums were within the ranges between (91.92– 89.03%) respectively, these outcomes fell within the international specifications [33]. It is important that pH levels of Gums solution are ideal and consistent. The pH value depicts the action of hydrogen particles in watery solutions ordinarily on a scale of 0 to 14. Based on this pH scale, fluids are characterized as being acidic, alkaline or neutral [34]. In this study the pH values of Kakamut and Hashab Gums were slightly acidic ranges between (4.55– 4.42) respectively. The pH values of Kakamut and Hashab Gums are relatively similar to the values recorded by Siddig [35] and Omer [26] range between 4.7-5.7 for *A. polyacantha* gum, and *Acaci*a Senegal gum, respectively. Optical rotation refers to rotation of plane of polarization of directly polarized light as it goes through specific materials. Optical rotation is use to determine the nature of sugars in Gum Arabic acquired from *Acacia* species. The International specifications of quality parameters of Gum Arabic determined that the best quality Gum Arabic must have negative optical rotation [36]. In the present study, the optical rotation was within the range of (-12.02° – -28.06°) for Kakamut and Hashab Gums respectively. These findings were relatively similar to the recent results of Omer [26], who reported -13.5 to -26.0 specific rotation for *A. polyacantha* gum but were higher than the values of -10.3° and -7 to -13° provided by Biswas [37] and Siddig [35], respectively. Viscosity is the measure of the interior friction of a liquid. This friction becomes obvious when a layer of liquid is made to move in relation to another layer. Gum Arabic is additionally an important hydrocolloid since it is compatible with an incredible number of polymers and it is as often as possible utilized to lessen the thickness of various fluid stages [38]. The findings revealed that viscosity of Kakamut and Hashab Gums were ranges between (113.06–89.09 mL/g). The present results obtained were higher than the values of 10.3 mL/g and 12.7 mL/g reported by Omer [26], and Siddig [35]. Their findings were significantly lower compared to the 14 mL/g intrinsic viscosity reported for *A. seyal* gum Elkhatim [10]. Purity simply means absence of impurities or contaminants in a substance. The determination of Gum purity, is one of the principal requirements evaluated in quality control of the pharmaceutical industry [33, 39]. The percentage of purity of Kakamut and Hashab Gums as showed in the results ranges between (99.98 – 99.92%) respectively, these results is in agreement with the international specifications [40]. Crude fiber is a measure of quantity of indigestible cellulose, pentosans, lignin, and other components of Gum [41]. The result showed that the percentage of the crude fiber of Kakamut and Hashab Gums were within the ranges between (3.44– 3.42%) respectively. The total nitrogen is the sum of nitrogen derived from amino acids that make up proteins [42].

The amount of protein present in Gum Arabic is commonly determined by analysis of the total nitrogen by the Kjeldahl method [43] and multiplying the nitrogen percent by factor 6.6 [21]. The present work showed that nitrogen and protein contents range between (0.27– 1.78%) and (0.20– 1.32%) were within the international specifications of Kakamut and Hashab Gums respectively. In the previous studies, the average nitrogen content (0.36% for Kadogli and 0.41% for Eldamazine) agreed with the earlier findings: 0.35% Karamalla, [35]; 0.33% - 0.36% Siddig, [25]; 0.34% Ishag, [44]; 0.38 to 0.40% Omer, [26]. Those results are relatively higher than our findings for Kakamut and Hashab Gums. In the recent studies, the average protein content in the two locations Kadogli and Eldamazine, was 2.24 and 2.56%, respectively, which is comparable to the values varying from 2.2 to 2.6% previously reported by Ishag, [44]; Karamalla [35]; Siddig, [25]; and Omer, [26]. Also, these values are relatively higher than our findings for Kakamut and Hashab Gums.

5. Conclusions

In summary, knowing the nutritional components of gum Arabic and proving that it is a nutrient and not just an additive has become very important in this century because of the necessity of support and continuation of food. The present study demonstrates that Kakamut Gum is considered one of the closest Gum to the Hashab Gum and the first contributor to Gum Arabic, Further study efforts should be directed to study the remaining physicochemical properties such as the ratios of sugars, amino acids, molecular weight and the proportions of a major and minor elements. The possibility of introducing in all food, pharmaceutical and cosmetic industries should also be studied.

Competing Interests

The authors have declared that no competing interests exist.

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