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Assessment of physico-chemical properties of gum-arabic of commerce from *Acacia senegal* found in different localities of Ethiopia

Dagnew Yebeyen[1,*] and **Fikremariam Haile**[2]

[1]Central Ethiopia Environment and Forest Research Center, Ethiopian Environment and Forest Research Institute, P.O. Box 30708, Addis Ababa, Ethiopia

[2]Wood Technology Research Center, Ethiopian Environment and Forest Research Institute, P.O. Box 2322, Addis Ababa, Ethiopia

*E-mail address: dagnewyeb@hotmail.com

ABSTRACT

A study was conducted to investigate the effect of growing location in the physico-chemical properties of gum arabic obtained from *Acacia senegal*. Authentic representative gum exudates samples were collected from Abederafi, Yabello, Awash and Filtu areas of Ethiopia. The experiment was conducted to determine Moisture content (MC), Ash content (Ash), pH, Relative Viscosity (RV), Nitrogen (N), Crude Protein (CP) and Mineral contents. Laboratory analyses were employed to determine the physico-chemical characteristics. The results were analyzed by using SAS Statistical Software. The analysis indicated that very high significant differences ($p < 0.001$) were seen on Ash, pH, RV, iron, calcium, and sodium contents of the gum arabic samples between the study sites. Furthermore, significant differences ($p < 0.05$) were indicated for N, CP, Cu, K contents. The results also showed MC, Mn and Mg contents have no significant difference among growing locations. According to our results, the percentage moisture content of the gum arabic samples were between 12.64 % and 13.41 %, while Ash percentage were between 0.32 % and 16.98 %. The mean pH values of the gum samples, obtained by employing different concentration of aqueous solutions also ranged between 4.4 and 4.97. In addition, the relative viscosity of the gum samples studied fall between 0.9 to 4.2 centipose, while Nitrogen and crude protein contents of the gum arabic samples from the study areas were from 0.313 % to 0.513 % and 1.943 % to 3.21 %, respectively. The major mineral element compositions of the gum arabic samples in descending order were Mg, Ca, Na, Cu, Fe, Mn and K. As compared to international standards and prior studies on gum arabic, the gum-arabic samples from the study sites have comparable physico-chemical characteristics.

Keywords**:** *Acacia senegal*, growing location, physico-chemical properties

1. INTRODUCTION

The dryland areas in Ethiopia which fall within the range of UNEP's definition of desertification cover 71.5% of the country's total land area. Out of the total estimated area of drylands in Ethiopia, 25 million ha is covered with woodland and bushland [1]. Accordingly, the woodland and savannah region covers some 20% of the total land area of Ethiopia. From this woodland and savannah, the *Acacia* woodland and savannah occupy various environments and accounts for some 11% of the total land area of Ethiopia. Such woodlands are also known for their plant, animal, and habitat diversity. Nonetheless, they are also very fragile ecosystems that could be drastically affected by over exploitation and mismanagement [2].

The exploitation and management of "Non–Timber Forest Products" (NTFPs) is increasingly proposed as a potential means of ensuring sustainable management of forests and their biodiversity. NTFPs are frequently touted as important to household consumption, and as a way to maintain or to increase the value of standing forest and thus to discourage deforestation [3]. Thus, management of NTFPs cannot be seen separately from general forest management, which, unlike forest plantation, affects vegetation and biodiversity in general.

In the dryland woodlands of Ethiopia several species in the genus *Acacia*, *Boswellia*, *Commiphora* and *Stericulia*, know to hold commercially important NTFPs such as gum arabic, frankincense and myrrh, are predominating the vegetation composition [4]. Ethiopia is known as one of the world leading producers and exporters for some of these NTFPs with significant socio–economic contributions at both national and local level [5]. Apart from essential oils, which provide an array of flavours and fragrances, gums, resins and latexes are perhaps the most widely used and traded category of NTFPs other than items consumed directly as foods, fodders and medicines, which indicates the potential for commercial promotion of the products in Ethiopia. Besides their economic significance several species of *Acacia*, *Boswellia* and *Commiphora* could be managed to provide, concurrently, multiple ecological services that will help to fight desertification and soil erosion by water and wind, contribute to the conservation and enhancement of biodiversity, improve soil fertility, and provide an opportunity for C–sequestration.

One of the most recognized NTFPs products of the dryland vegetation of Africa in general and that of Ethiopia in particular is gum arabic. The major source of presently traded gum-arabic is *Acacia senegal* (L) Willd. The use of gums has declined today, compared with the early part of the 20th century. The decline is a preference for raw materials of consistent, predictable quality, which are not subject to the vagaries of weather, insect pests, stability in producing countries, and price. Despite the changes the demands for gum will continue and even bound to increase in the future for several reasons such as consumers' preference for natural products. This is good news for people in the producing countries, provided that due attentions are given to such aspects as quality control and sustainable management of the resources.

One factor observed to influence the quality of gum arabic is botanical origin. Quality of gum arabic differs between and within species [6]. Gums from different species exhibit characteristics that are intrinsically different. Even within the same species, different varieties produce gum with different characteristics. Because of the stringent regulations imposed on all food additives, gum arabic, like all other food ingredients, is subjected to extensive toxicological control by countries, organizations and users of the product, which aim to protect the consumer of processed foods containing additives, and thus to ensure the freedom of gum arabic from toxicological hazards. To achieve this end and get in to the market, gum arabic for commerce must conform to certain chemical specifications [7]. Chemical analysis and quality assessment have been carried out on gum exudates from a large number of *Acacia* species (as well as gum– arabic– like exudates from other genera), but relatively little detailed information is available on the intra–specific variation of *A. senegal* gum. In–depth physicochemical screening is needed, to learn more about between–site, between–tree and seasonal variations in gum quality.

Moreover, compared to other producer countries, very little studies have so far been done on the physicochemical characteristics of gum arabic of Ethiopian origin. In order to promote the commerce of gums and gum resins, knowledge on the chemistry for each gum or resin type is crucial. However, very little work has been carried out for characterization of gums of Ethiopian origin. Thus, lack of such studies could be mentioned as one bottle neck for expanded commercialization of gums of Ethiopia. The objective of this study was, therefore, to investigate the effect of geographical origin in the physico-chemical properties of gum-arabic obtained from *Acacia senegal* (Figure 1).

Figure 1. *Acacia senegal* (L) Willd

2. MATERIALS AND METHODS

2. 1. STUDY AREA

The study was conducted in the *Abederafi*, *Yabello*, *Awash* and *Filtu* areas of Ethiopia. Representative sites were selected from different regions of Ethiopia so as to include different populations of *A. senegal*. Description of study sites is expressed in Table 1.

2. 2. SAMPLE COLLECTION

Authentic representative *Acacia senegal* gum samples were collected from the study sites during the dry seasons. The collected gum samples were put into perforated plastic bags, labeled and safely transported to Forestry Research Center. Impurities such as wood pieces and sand particles were carefully removed. The samples were then; air dried for fourteen days and ground using a pestle for further physic-chemical analysis.

Table 1. Description of the study sites

Study Site	Regional State	Altitude in m asl.	Annual Rainfall in mm	Mean Annual Temperature in °C
Abederafi	*Amhara*	550 - 950	885	27.8
Yabello	*Oromia*	1350 - 1800	588	19
Awash	*Afar*	980	567	25.8
Filtu	*Somalli*	1150	450	27

2. 3. PHYSICOCHEMICAL CHARACTERISTICS ANALYSES

Analysis on the physicochemical characteristics of the gum arabic was done in the laboratories of Deberezeiet Agricultural Research Center and Addis Ababa University. The physico-chemical properties of the gum analyzed include moisture content, ash content, pH, viscosity, nitrogen content, crude protein and mineral contents. The laboratory procedures used for the analysis of physicochemical properties of the gum arabic samples are presented as follows.

2. 3. 1. DETERMINATION OF MOISTURE CONTENT

Accurately 2 grams of grounded gum arabic sample was weighed and oven dried at 105 °C for 5 h. Oven dry weight was taken after allowing the samples to cool in a desiccator before reweighing. The experiment was done in three replications and an average of the three replicates was taken. Moisture content (MC) was expressed as a percentage of the weight loss from the original weight [8].

2. 3. 2. DETERMINATION OF ASH

Accurately 2 grams of the gum arabic sample was first heated on a burner in air to remove its smoke. Then it was burned in a furnace at 550 °C. The ash content was expressed as a percentage ratio of the weight of the ash to the oven dry weight [8].

2. 3. 3. DETERMINATION OF pH

A 25% gum solution was prepared and the pH meter was calibrated with a standard solution of known pH. The pH measurement of the gum solution was read from the instrument [8].

2. 3. 4. RELATIVE VISCOSITY

The Relative viscosity of the gum arabic samples was measured at 25 °C by the use of viscometer [9]. The viscosity in centipose was calculated thus:

$$\text{Viscosity (25 °C)} = T – To / To$$

where: T = Flow time of 1% of 100 gl^{-1} gum arabic solution and To = Flow time of distilled water. (All times were measured in seconds).

2. 3. 5. DETERMINATION OF TOTAL NITROGEN AND CRUDE PROTEIN

Exactly 0.5 gram of each gum arabic sample, in duplicate, was weighed and transferred to Kjeldahl digestion tube plus one Kjeldahl tablet, copper sulfate-potassium sulfate catalyst. Then 10 mls of concentrated, nitrogen free, sulfuric acid were added. The tube was then mounted in the digestion heating system which was previously set to 240 °C and capped with an aerated manifold. The solution was then heated at the above temperature until a clear pale yellowish-green color was observed which indicates the completion of the digestion. The tubes were then allowed to cool to room temperature. Their content was quantitatively transferred to Kjeldahl distillation apparatus followed by addition of distilled water and 30 % (w/v) sodium hydroxide. Steam distillation was then started and the released ammonia was absorbed in 25 ml of 2 % boric acid. Back titration of the generated borate was then carried out in the versus, 0.02 M, hydrochloric acid using methyl red as an indicator. Blank titration was carried same way. The percentage of nitrogen (N) content was then calculated [10]. The crude protein (CP) content was calculated using the nitrogen conversion factor of 6.25 as proposed by [11].

2. 3. 6. DETERMINATION OF MINERAL CONTENT

Ash from a sample of gum arabic was prepared and dissolved in concentrated sulfuric acid. Then the solution was used for the determination of the minerals studied except for phosphorus by an atomic absorption spectrometer. 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. Wet ash method was used for the determination of phosphorus in the gum sample. The ash was dissolved in vanadomolybdic acid reagent in which phosphate reacts to form a yellow molybdovanadophosphoric acid. Finally, the amount of phosphorus was determined using a UV–VIS spectrometer at 400nm in 1 cm cells, and expressed as percentage of Na_3PO_4 [12].

2. 4. DATA ANALYSIS

The physicochemical data were subjected to Analysis of Variance (ANOVA) statistical method using Generalized Linear Models Procedure (GLM). A total of four location treatments with three replications and nine physicochemical parameters were designed in the experiment. Statistical analysis of data was carried using SAS Software, Version 9 and Microsoft Excel (2010) computer software. Means that exhibited significant differences were compared using Least Significant Difference (LSD) at ($P < 0.001$) level.

3. RESULTS AND DISCUSSION

A number of physicochemical and chemical methods were employed to characterize the *A. senegal* gum arabic samples. It was found that a very high significant difference on ash, pH, viscosity, iron, calcium, and sodium contents for the gum arabic samples among study sites (Table 2). There was also a significance difference for nitrogen, crude protein, cupper, and potassium contents. Moisture content, manganese and magnesium compositions showed no difference for the samples between locations. Table 3 presents the laboratory analytical data for the physico-chemical characteristics of the gum arabic samples collected from the four study sites.

Table 2. Analysis of Variance for characterization of gum from *A. senegal* for different test parameters.

SV	DF	Mean Square												
		MC	pH	VS	ASH	N	CP	Cu	Mn	Fe	K	Ca	Na	Mg
LOC	3	0.41ns	0.17***	0.07***	159.2***	0.02*	1.01*	6793*	41673.7ns	8826.4***	0.56*	475166***	51205***	128369ns
CV		2.95	1.32	12.05	23.18	14.41	14.37	0.76	16.81	15.56	25.46	13.13	30.59	24.27
R^2		0.5	0.95	0.96	0.97	0.72	0.72	18.5	0.98	0.88	0.73	0.93	0.89	0.27

***: Significant at p = 0.001; **: Significant at p = 0.01

The international specifications state that quality parameters of gum arabic must conform to certain chemical specifications. The parameters are meant to identify and characterize the toxicological risks and hazards and provide the assurance that gums have not come from other tree species so as to maintain and sustain high gum quality in the world market. The percentage moisture content of the gum arabic samples falls between 12.64 % and 13.41 %, while Ash percentage were between 0.32 % and 16.98 % (Table 3). FAO food and nutrition paper 52 specifies that the loss on drying and total ash percentage as a purity test for gum arabic should not exceed 15% and 4% respectively [13]. The moisture contents of the gum arabic samples from the study areas fit the international standard. While the ash contents from most of the study areas are in agreement with recommended specifications of quality parameters of gum arabic. However, the ash content found in one of the study sites, *Abederafi*, is far out of the range. This may be due to edaphic factors in the area. The least ash content was also observed from *Awash,* 0.32% *(*Table 3).

The mean pH values of the gum samples, obtained by employing different concentration of aqueous solutions from three readings, range between 4.4 and 4.97 (Table 3), which are to some extent acidic. The result is in good agreement with reported pH values of gum arabic studies by previous authors such as [6,8,14]. The relative viscosity of the gum samples studied fall between 0.9 to 4.2 centipose. The results obtained for all gum samples agree with the values found in Mhinzi and Mrosso [15] except samples from *Abederafi* area. Viscosity is a measure of the resistance of flow due to internal friction when one layer of fluid is caused to move in relationship to another layer.

FAO food and nutrition paper 52 [16] includes in its definition of gum arabic that it consists mainly of high molecular weight polysaccharides and their calcium, magnesium and potassium salts. Table 3 shows that calcium, magnesium, sodium, iron, manganese and copper are the most abundant elements in the gum arabic samples from the study areas. In all mineral parameters measured there is a significant difference between gum arabic brought from different geographical locations except for manganese and magnesium (Table 2).

The high significant variation indicates that there is a considerable variation in soil parent material from one area to another. Lelon et al. [17], in their study also showed that there is a strong correlation between soil chemical properties with gum arabic compositions proving the effect of soil conditions as factors influencing quality parameters of gum arabic.

The amount of copper for the gum arabic samples of the study sites analyzed in the experiment were found between 116.55 and 226.66 mg/kg. The values are higher than the amount of copper found from previous studies on gum arabic from *A. senegal var. senegal* from Sudan, 52 to 66 mg/kg [18]. Higher Iron content was recorded for gum arabic samples from *Yabello* (192.12 mg/kg) while the least iron content was observed from *Filtu* (55.7 mg/kg) (Table 3). The Iron content for the gum arabic samples collected from all the sites are lower than the international specification, 730 to 2490 mg/kg [18].

Significantly higher cationic composition of potassium was obtained at *Abederafi* (1.7mg/kg) and *Awash* (1.32mg/kg) than *Filtu* (0.6mg/kg) and *Yabello* (0.67mg/kg) (Table 3). The value is lower than what was reported on our previous work and other reports on gum arabic [8], [15]. Highly significant cationic composition but statistically similar values of calcium were recorded both for *Awash* and *Filtu* areas (1355.9mg/kg and 1233.6mg/kg respectively). Least value was recorded at Abderafi with the value of 445.04 mg/kg. In all study sites the experimental data were found lower than the same reports referred above. Except, gum arabic samples from *Yabello* site, all study areas had statistically similar sodium content (Table 3). In this study the sodium content of the gum arabic from *Abderafi* (145.2 mg/kg) is within the value reported by Mhinzi and Mrosso [15] (100 to 200 mg/kg). The sodium content values from *Awash* and *Filtu* sites are also not far from the report.

Table 3. Physicochemical properties of gum arabic samples from the study sites.

Location	Parameters												
	MC	**ASH**	**N**	**CP**	**VC**	**pH**	**Cu**	**Mn**	**Fe**	**K**	**Ca**	**Na**	**Mg**
Yabello	13.41^{a}	4.04^{b}	0.49^{a}	3.11^{a}	2.5^{b}	4.4^{a}	116.55^{b}	28.22^{b}	192.12^{a}	0.86^{bc}	901.84^{b}	1.16^{c}	1333.6^{a}
Abederafi	12.64^{b}	16.98^{a}	0.513^{a}	3.21^{a}	0.9^{d}	4.88^{a}	226.66^{a}	273.54^{a}	130.87^{a}	1.7^{a}	445.04^{c}	145.2^{b}	1723.2^{a}
Awash	13.27^{ab}	0.32^{bc}	0.313^{b}	1.943^{b}	4.2^{a}	4.64^{b}	139.13^{b}	34.36^{b}	178.2^{a}	1.32^{ab}	1355.9^{a}	288.33^{a}	1578.7^{a}
Filtu	13.41^{a}	4.04^{b}	0.497^{a}	3.11^{a}	3.9^{a}	4.97^{a}	161.84^{b}	42.61^{b}	55.7^{c}	0.6^{c}	1233.6^{a}	252.2^{a}	1850.4^{a}

Values with same alphabets are not significantly different from each other

Nitrogen and crude protein contents of the gum arabic samples from the study areas are shown in Table 3. As indicated in the table, the nitrogen and protein contents of the samples were 0.313 % to 0.513 % and 1.943 % to 3.21 % respectively. From the experiment it is observed that there is a significant difference in nitrogen and crude protein content for gum arabic samples brought from different locations (Table 2). Highest and identical values were observed for samples from *Yabello* and *Filtu* areas and the least from *Awash* (Table 3). The nitrogen and crude protein values are in good agreement with the international specifications of quality parameters of gum arabic and with the values obtained from other studies [6], [8], [18].

4. CONCLUSIONS

From this study it can be concluded that gum arabic samples from *A. senegal* trees of the study areas meet most of the specifications given by the 'Joint Expert Committee for Food Additives for Gum Arabic'. It is also found that there is a significant difference in many of the physicochemical characteristics analyzed for the gum arabic samples brought from different locations. Viscosity and Ash contents of gum samples brought from *Abederafi* site were different from gum Arabic samples brought from the rest of the study areas and the international standards. Hence, further study is needed as to the edaphic factors and species variety identification of the *A. senegal* trees found in the area. The gum arabic from the study areas can be considered to be truly gum arabic from *Acacia senegal* trees from the dry land areas of Ethiopia. It can also be considered as a potential source of quality gum arabic that can be exploited for commercial purpose, based on the physico-chemical properties analyzed. However, it can further be subjected to broader analysis in terms of molecular characterization and emulsification properties for the purposes of quality control.

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