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Research Article

Physico-Chemical Properties of Some Selected Plants Gum Exudates in Ghana

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Abstract

Gums used in Ghana are chiefly imported, while locally produced gums have not been exploited commercially due to lack of data on the physio-chemical properties which influence their application in industries. This study was therefore undertaken to assess the suitability of gums obtained from cashew, neem, moringa and mango trees in Ghana for industrial application based on their physico-chemical properties using *Acacia albida* (acacia gum) as a control. The physico-chemical properties determined using standard protocols for food analysis include pH, ash, nitrogen content, phosphorus (P), iron (Fe), calcium (Ca), sodium (Na) and potassium (K). The pH, ash, nitrogen content, P, Fe, Ca, Na and K of the gums studied ranged from 4.70 - 6.54, 2.0 - 4.0%, 0.48 - 2.06%, 0.017 - 0.028 mg/kg, 0.16 - 0.35 mg/kg, 0.54 - 1.44 mg/kg, 0.06 - 0.10 mg/kg and 0.22 - 0.82 mg/kg respectively. The pH values the gums studied were within slightly acidic to neutral scale with *Anacardium occidentale* (cashew) and *Mangifera indica* (mango) gums having similar pH values as acacia gum. Physico-chemical properties of the selected plants gum exudate studied were comparable with acacia gum which is already applied in food. Thus *Anacardium occidentale* (cashew), *Mangifera indica* (mango), *Moringa oleifera* (moringa) and *Azadirachta indica* (neem plant) gums could be used as a good substitute for acacia gum in food and pharmaceutical applications. Essential minerals analysed in the selected gum samples were found in level far below the recommended dietary intake.

Keywords: *Neem Gum; Acacia Gum; Mango Gum; Cashew Gum; Moringa Gum; Physico-Chemical; Minerals*

Introduction

Plant gums are exudates that either ooze spontaneously or after mechanical injury by insects, animals, drought or storms to fruits, trunks or branches of the trees [1]. They are used in the food industry as binding agents, clarifying agents, emulsifiers, stabilizer and as thickening agents [2,3].

The characteristics of plant gums may vary significantly depending on the geographical origin, age of the trees, climatic conditions, soil, and environment and on the place of exudation on the tree [3]. Physico-chemical compositions of plant gums are needful to ascertain its usefulness in food and pharmaceutical industry. It has also been found out that acidic and neutral gums have useful commercial value in the food industry [4].

However, only viscosity, rheological properties of cashew gum have been reported for locally produced gums in Ghana [5-8].

Minerals like zinc, copper and manganese are necessary for superoxide dismutases in both cytosol and mitochondria. Iron is a component of catalase, a heme protein, which catalyzes the decomposition of hydrogen peroxide. Small amounts of micronutrients (minerals and vitamins) along with macronutrients are required to maintain a sound physical condition. Sodium, potassium, iron, calcium and many trace elements together with antioxidant vitamins and minerals are vital for the body [9].

A survey conducted in Ghana revealed that not only is about 10,000 kg of gum used by various food and pharmaceutical industries annually, but also are mostly imported [10]. This means a huge market exists for gum utilization in Ghana, and this has to be utilized for the benefits of the citizenry. Against the backdrop of the continuous depreciation of the Ghanaian currency, the Ghana Cedi, over-reliance of the food industry on the external supply of gums is likely to increase their cost and hence the cost of the final food product. However, the potential to exploit gum resources exists in Ghana.

Many plants are known to produce gums at commercial quantities in Ghana and the ones that have been reported include: *Acacia campylacantha*, *Albizia zygia*, *Albizia adianthifolia*, *Khaya senegalensis*, *Khaya grandifoliola*, *Sterculia setigera*, *Sterculia tragacantha* and *Anacardium occidentale* [4]. The cashew tree (*Anacardium occidentale*) is being grown commercially in Ghana and it produces appreciable amounts of gum [5]. Cashew tree has been cultivated for food, medicine and more recently has been used in the manufacture of adhesive, resins and natural insecticides [11]. The acacia tree (*Acacia senegal* L.) is an invasive plant in Ghana that produces gum arabic, stabilizes sand dunes, fixes atmospheric nitrogen and is a source of fence posts, firewood and fodder [12]. Mango is globally considered as one of the finest fruits and important crop in tropical and subtropical regions of the world [13]. The cultivation of mango is a major farming activity in Ghana with the YiloKrobo Municipality having a comparative advantage of a bimodal mango production system [14]. Aside mango trees providing the finest fruits, the tree serves as landscape shade and leaves and bark are for medicinal preparations. There are millions of neem trees growing in Ghana, especially in the coastal and interior savannahs [15]. Many of these trees are used for the production of firewood, charcoal and in recent years there has been interest in neem in Ghana for crop protection, both in the field and storage. Different parts of neem (leaf, bark and seed oil) have been shown to exhibit wide pharmacological activities including; antioxidant, antimalarial, anti-mutagenic, anti-carcinogenic, anti-inflammatory, anti-hyperglycaemic, antiulcer and anti-diabetic properties [16].

Ghana is among the major production sites of *Moringa oleifera* in the world [17]. The uses of *Moringa oleifera* species are diverse, including human foods, animal feed. Seeds are used for the production of cooking oil, biodiesel. Various medicinal compounds are obtained from all parts of the plant [17,18]. So far these sources have not been tapped for their gum resources in Ghana, perhaps due to limited or lack of data on the properties that influence their uses in various industries. Based on the above background, the study was conducted to assess the physic-chemical properties of some gums produced from trees in Ghana, and to determine their suitability in the food and pharmaceutical industry.

Materials and Methods

Source and Gum Preparation

Gums from five plants being; Cashew (*Anacardium occidentale*), Moringa (*Moringa oleifera*), Mango (*Mangifera indica*), Acacia (*Acacia albida*) and Neem (*Azadirachta indica*) used for the study were collected from Botanical Garden of Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. The gums were collected and prepared according to procedure used by Owusu., *et al* [4]. The trees were tapped horizontally on trees barks and left for one week. After this period hard dried nodules of gum were collected. The gums were handpicked to remove pieces of bark, dirt and other woody materials. They were then dried in the sun for about two weeks, milled and sieved through 2 mm. The samples were kept in labeled plastic containers for analysis.

Physicochemical methods

Total ash content

Two grams of powdered gum samples were weighed into a pre-weighted silica crucible. The gums were then incinerated in a muffle furnace at a temperature of 450°C for 2 hours and carbon free ash was obtained. The weight of the ash was expressed as a percentage of the air-dried gum in triplicates Analysis of Association of Analytical Chemists [19]. The percentage ash was calculated using the formula: X-Y/W x 100; where X = weight of crucible + ash, Y = weight of crucible

W = weight of sample to be determined in (g) before ashing.

pH

Two grams of each gum were dispersed in 100 mL of distilled water at room temperature as used by Owusu., *et al* [4]. A pH meter (HI 9024, HANNA Instruments) was standardized using the pH 4 and 7. The pH of the gum solutions was determined in triplicates.

Nitrogen

Nitrogen content in the gum samples were determined by a modified method given in AOAC [19] using the Kjeldahl system (Büchi, Flawil, Switzerland). The samples were digested in sulphuric acid in the presence of a catalyst. The acid solution was made alkaline with sodium hydroxide solution and nitrogen in the form of ammonia was distilled and collected in a 2% boric acid solution. The amount of nitrogen was determined by titration with 0.1M hydrochloric acid.

Digestion and determination of metals

Gum samples were dry digested by technique defined in AOAC [19]. One gram of the gum samples were weighed into a clean ceramic crucible and placed in a muffle furnace for 2 hours at a temperature of 500°C. The samples were removed from the oven and were poured into a numbered centrifuge tube. The samples were shaken for 5 minutes for proper mixing and again centrifuged for 10 minutes. The samples were then decanted into a clean 100 ml volumetric flask and make up with distilled water. This solution was used to determine sodium, iron, phosphorus, potassium and calcium.

Determination of potassium (K) and (Na) were done using flame photometric method with JENWAY PFP7 flame photometer. Phosphorus content was determined in the digested samples following the phosphomolybdenum blue method described by Murphy and Riley [20]. In this method, 10 ml of the sample solution was transferred into a 100 ml volumetric flask. 10 ml of vanadomolybdate reagent was added and volume made up to 100 ml. The sample was kept for 30 minutes for colour development. A stable yellow colour was developed. The sample was read on the Spectronic 20 spectrophotometer at 420 nm. A calibration curve was prepared using of analytical grade KH_2PO_4 and P content of the flasks calculated from the equation of line. Determination of calcium and iron was done using atomic absorption spectroscopy method with Spectra AA 220 atomic absorption spectrometer equipped with multiple hollow cathode lamps. The instrument was calibration using different concentrations of standard solutions of Ca and Fe. The result was expressed in mg/kg.

Quality control

Calibration curve was prepared for various elements using triplicate of serial dilution standard solution. Detection limit was determined with blank solution and spike recovery was performed for various elements by adding 50 mg of each element to one of the samples and followed the same digestion procedure and determination. The amount recovered was then calculated. Precision of the instrument was determined by running on sample for eight times and calculating the standard deviation.

Statistical analysis of data

The data obtained from the study were analyzed using GraphPad Prism (Version 6.01, San Diego, USA) and means were considered significant at $p < 0.05$. The values of the physico-chemical parameters were subjected to one-way ANOVA and Tukey's multiple comparisons analysis to test for variation in values found in various plant gums and with respect to acacia gum (control). The p-values of less than 0.05 were considered to be significant.

Results and Discussion

Result of quality control analysis

The procedures taken to ensure the validity of the metal analysis data in this study have been described in the method section above. The recoveries, regression co-efficiencies and detection limits of the elements analysed are presented in table 1 below. The linearity expressed as regression coefficient values of all the metals ranged from 97% to 99%. The recoveries obtained in this study ranging from 95% to 98% were with the acceptable limits of 95% to 100.4% [21].

Element	Detection limits (ppb)	Precision (%CV)	Recovery (%)	Regression coefficient (R^2)
Ca	2	3	97	99
Na	1	5	95	98
K	1	4	95	97
Fe	3	4	96	97

Table 1: *Recoveries, regression co-efficiencies and detection limits of elements.*

Physico-chemical properties of gums

pH is a logarithmic scale used to specify the acidity or basicity of an aqueous solution. The pH of the gums ranged from 4.70 to 6.54 (Figure 1a), with cashew gum recording the lowest and neem gum the highest. The pH for cashew gum (4.7) in this present study is slightly comparable with the pH of 4.2 found by Gyedu-Akoto., *et al*. [8] for cashew gum collected from Forest Research Institute of Ghana, Kumasi. The most widely used exudate gums in the food industry is gum arabic, gum tragacanth and gum karaya which have their respective pH ranges as 4.5 - 5.5, 5.0 - 6.0 and 4.4 - 4.7 [3]. Considering these pH ranges, the gums studied could be used as a perfect substitute for gum arabic, gum tragacanth and gum karaya which are widely used in the food industry. One-way ANOVA applied on all the data sorted by various plant gums revealed significant difference in pH ($P< 0.05$) between control sample (gum acacia) and the other plants gum. However, Tukey's multiple comparisons test showed no significant difference in total ash ($P < 0.05$) between control sample (gum acacia) and gum Moringa, control sample (gum acacia) and gum Cashew, control sample (gum acacia) and gum Mango, but showed significant differences between control sample (gum acacia) and gum Neem. It has also been found out that acidic and neutral gums have useful commercial value in the food industry (Tyler., *et al.* 1981). Hence making the gums samples studied to be potential sources of gum for commercial value in the food industry.

Ash is the inorganic residue remaining after the water and organic matter have been removed by heating in the presence of oxidizing agents, which provides a measure of the total amount of minerals within a food. Total ash content of the gums studied ranged from 2.0 - 4.0% (Figure 1b), and fell within the acceptable level of 4.0% (Belitz., *et al.* 2004). The total ash content for cashew gum studied (4%) was higher than the maximum total ash (2.6%) reported by Gyedu-Akoto., *et al.* [7] for cashew gum collected from Forest Research Institute of Ghana, Kumasi and 1.95% reported by Owusu., *et al.* [4] for cashew gum collected from the Ejura Farms Ltd., Ejura in the Ashanti Region, Ghana. The difference could be due to the fact that, ash content which is a crude indicator of mineral content [22] could vary for the same plant from place to place, because the mineral content of the soil varies according to the location in which the plant is grown [23]. One-way ANOVA applied on all the data sorted by various plant gums revealed significant difference in total ash ($P < 0.05$) between control sample (gum acacia) and the rest of plants gum. However, Tukey's multiple comparisons test showed no significant difference in total ash ($P< 0.05$) between control sample (gum acacia) and gum moringa with the rest of gums showing significant differences.

Phosphorus is an essential structural component of cell membranes and nucleic acids but is also involved in several biological processes, including bone mineralization, energy production, cell signaling through phosphorylation reactions, and regulation of acid-base homeostasis.

Total phosphorus of the various exudates studied ranged from 0.017 to 0.028 mg/kg (Figure 1c). The exudate from Cashew had the highest phosphorus content while neem exudate had the lowest phosphorus content. Its difference between other plants gum are statistically insignificant ($p = 0.9$). Recommended dose of phosphorus to the human body for men is 800 mg/day and for women are 1200 mg/day and 1250 mg/day for children. Your body needs phosphorus for many functions, such as filtering waste and repairing tissue and cells.

The general recommended dietary allowance of phosphorus for healthy adults has been set to be700 mg/day [24] while Food and Nutrition Board of US had set recommended dietary allowance of phosphorus for men to be 800 mg/day and for women to be 1200 mg/day, 1250 mg/day for children and 100 - 125 mg/day for infant [25]. The dietary P for the maximum P concentration in the samples would be 0.028 mg which is less than 1% of the recommended dietary allowance for adults in general. Hence the P concentration in the gum samples studied would not exceed the recommended dietary allowance when used in food industry. Phosphorus contents of gums were found to be lower than mean P concentration (5.8 ppm) for cashew fruit grown in different regions of Tanzania [26].

Nitrogen is a naturally occurring element that is essential for growth and reproduction in both plants and animals. Total nitrogen (N) content, a parameter used to evaluate the plant's nutritional status obtained for the samples studied ranged from 0.48 - 2.06% (Figure 1d). Gum from cashew plant recorded the highest nitrogen content while Acacia gum sample recorded the lowest. The latter was within the nitrogen content (0.19 to 0.62%) reported for Acacia Senegal gum from Sudan [27] and nitrogen content (0.45 - 0.92%) of *Anogeissus* *leiocarpus* gum from Abojebiha, Sudan [28]. Analysis of variance showed that among the various gum samples from different plants there is a significant difference in nitrogen content ($P < 0.05$). Studies have revealed a strong relationship between leaf chlorophyll content and plant N content [29]; hence the plausible cause of significant variation in nitrogen content from in various plants gum.

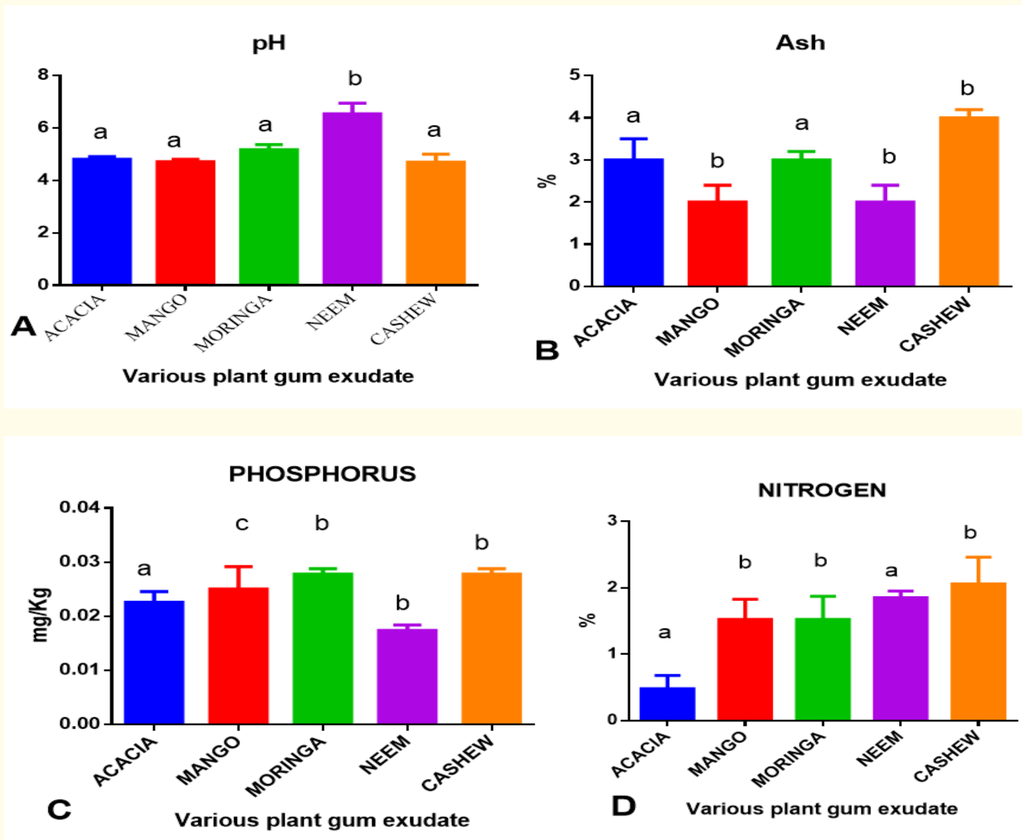

Figure 1: *Physico-chemical properties of gum samples.*

Minerals play an important role in the human body. Potassium contributes to the maintenance of cell organization and permeability, calcium plays an important role in the growth of skeletal tissue, in the metabolic regulations of bio-molecules as coenzymes, magnesium is involved in nervous system stability and muscle contraction and iron is the most important element in the prevention of anemia, and it is a core element of red blood cells [30]. According to Vesk and Allaway [31], minerals in plants are commonly attributed by the environmental factors including air, water and the soil where the plant grows. Metal ions of calcium, iron, potassium and sodium, are essential minerals needed by the body to satisfy its metabolic needs and were found in cashew, mango, moringa, Acacia and neem gum samples studied. In general, metals concentration in all the gum samples studied are in the decreasing order as follows: Ca > K > Fe > Na. Concentration of sodium in various plant gum exudates studied ranged from 0.06 to 1.10 mg/Kg (Figure 2a). The exudates from mango and moringa had the highest sodium content while gum exudates from cashew plant recorded the lowest sodium content. The variance between all the various plants gum was not significant ($P = 0.3$). The recommended dietary allowance of sodium for healthy adults is

2000 mg sodium per day [32]. Consumption almost 2000 Kg of gum during the day will supply the full amount of body need for sodium. Since this is practically impossible, the concentration of sodium found in the gum samples would not exceed the recommended dietary allowance when used in the food industry.

Iron concentration of the various plants gum exudate studied ranged from 0.16 to 0.35 mg/kg (Figure 2b). The exudates from neem, cashew and acacia plant had the highest iron content (0.35 mg/kg) while gum mango and gum moringa recorded the lowest iron content (0.16 mg/kg). The variance between all the various plants gum was significant ($P < 0.001$) and Tukey's multiple comparison of Fe concentration of gum acacia (control) with gum mango and gum moringa was significant ($P < 0.05$) while gum acacia (control) with gum cashew and gum neem were insignificant ($P > 0.05$). The daily requirement of iron in the human body, according to the Food and Agriculture Organization for mature women is 15 mg/day and for adult men 10 mg/day [32]. From the recommended dietary intake, the body need for Fe could only be provided by consumption of approximately 100 kg of analyzed gums. Calcium concentration of gum samples studied varied from 0.54 to 1.44 mg/Kg (Figure 2c). The exudates from acacia had the highest calcium content and cashew has the least calcium content. One way ANOVA between all Ca concentration in the plants gum studied was not significant ($P = 0.02$). The analysis of variance revealed that, different plants had no significant influence on the level of Ca in the analyzed gums. The daily requirement of calcium in the human body, according to the Food and Agriculture Organization for mature women is 1300 mg/day and for adult men 1000 mg/day [32].

The exudates from moringa had the highest potassium content of 0.82 mg/kg while gum neem had the lowest potassium content of 0.38 mg/kg (Figure 2d). The highest concentration of K in the samples analyzed. Recommended dose of potassium to the human body for adult is 15 mg/day [32]. The variance between K concentration in all the various plants gum was significant ($P < 0.001$) and Tukey's multiple comparison of K concentration of gum acacia (control) with gum mango and gum moringa was significant ($P < 0.05$) while gum acacia (control) with gum cashew and gum neem were insignificant ($P > 0.05$).

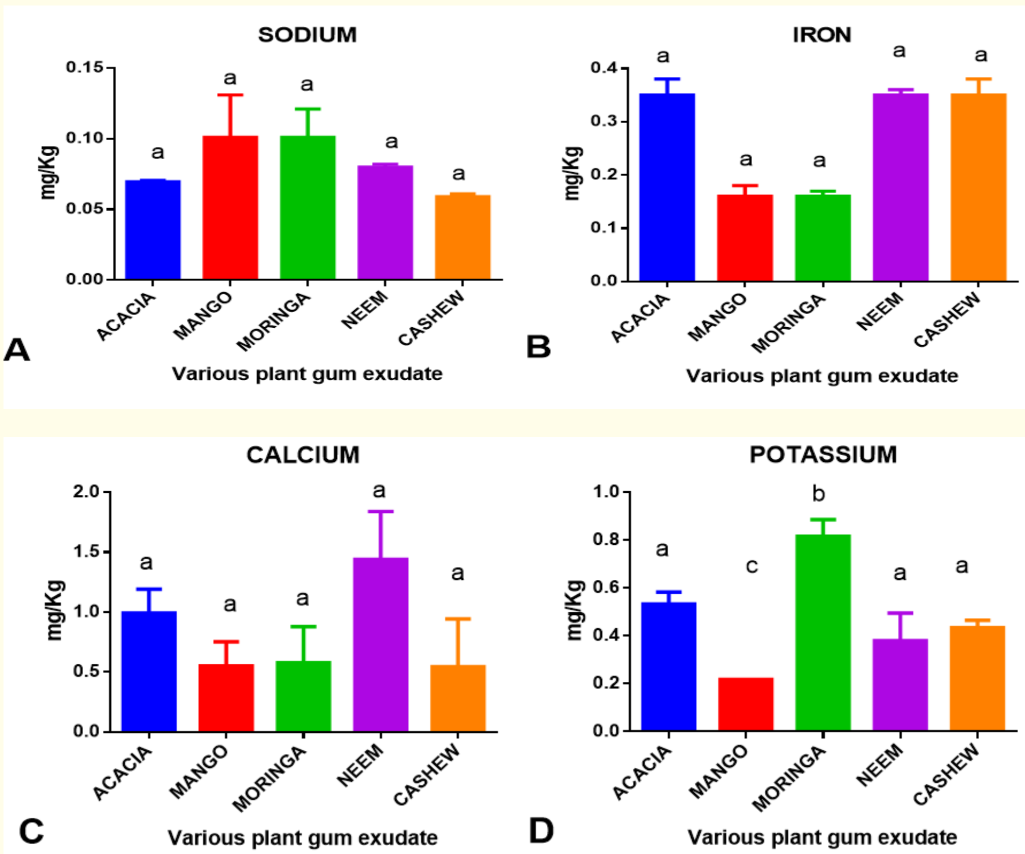

Figure 2: *Measured mineral content of gums.*

Conclusion

The results obtained from this study revealed that the physio-chemical properties of the selected plants gum exudate in Ghana are comparable with acacia gum which is already applied in food. Thus cashew, mango, moringa, and neem plant gums could be used as a good substitute for acacia gum in food and pharmaceutical applications.

In general, metals concentration in all the gum samples studied are in the decreasing order as follows: Ca > K > Fe > Na. Metal ions of calcium, iron, potassium and sodium, which are essential minerals needed by the body to satisfy its metabolic needs were found in cashew, mango, moringa, Acacia and neem gum samples studied in below far below the recommended dietary intake.

The analysis of variance indicated significant different in levels of Fe, K, pH, N and ash content in the gum samples studied, indicating that plants had significant influence on these parameters analyzed in the gums samples.

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Competing Interests

The authors declare no competing interest.

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