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Physico-chemical and Rheological Properties of Karaya Gum (*Sterculia urens* Roxb.)

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A B S T R A C T

Physico-chemical and rheological properties of any material are important from industrial point of view in order to understand the requirement of different process operations for its value addition as well as for its commercial utilization. The present study describes some of the important physico-chemical and rheological properties of *Karaya* gum. Efforts have been made to determine moisture content, bulk density, true density, tap density, bulkiness, porosity, Hausner's ratio, Carr's compressibility index (%), angle of repose (°), coefficient of friction (n) on glass, mild steel, plywood and rubber surfaces following the established methods for other similar food materials. The lumps of *Karaya* gum collected from the forest of Chhattisgarh were used in the present study. Both grits and powder samples were used for determination of the properties depending on the demand of the methodology. The values of different physical and chemical properties determined were; moisture content: 17.47 ± 0.44 (% wb), bulk density: 0.79 ± 0.02 (g/cm^3), true density: 1.50 ± 0.17 (g/cm^3), tap density: 0.90 ± 0.04 (g/cm^3), bulkiness: 1.26 ± 0.03 (cm^3/g), porosity: 46.76 ± 6.12 (%), hausner's ration: 1.14 ± 0.06, carr's compressibility index: 12.31 ± 4.19, angle of repose: 47.27 ± 2.91°, coefficient of friction 0.24 ± 0.03 N (glass), 0.43 ± 0.04 N (mild steel), 0.28 ± 0.01 N (plywood) and 0.47 ± 0.04 N (rubber), respectively. Values of ash content, pH, refractive Index, water activity, water holding capacity (per 100 ml), nitrogen (%) and protein (%) were determined to be 4.62%, 4.26, 1.336, 0.651, 84.76, 0.16 and 1.06, respectively. *Karaya* Gum is soluble in hot and cold water but insoluble in acetone, chloroform and ethanol. The viscosity of 1% *Karaya* gum solution was found to be varied from 619 to 1286 cp in the spindle rotational speed range of 20 to 100 revolutions per minute at room temperature of 24 -26^{o}C.

Introduction

Karaya tree is a native of dry deciduous forests of dry rocky hills land having tropical climate (Sao, 2013). It's height up to 15 m. The flower bloom from February to March and the tree bears star shaped flowers (Gupta *et al.*, 2011). One of the most important forest products of our country is *Karaya* gum. *Karaya* gum is the dried exudates obtained from the stem and branches of Sterculia tree, family *Sterculiaceae*. The gum is produced by genus Sterculia and is collected after tapping or blazing the tree or as natural exudates (A. Elkhalifa, A/ Wadoud and Ahmed Hassan, El Fatih). It is also known as Indian tragacanth and obtained from *Sterculia urens* Roxburgh. Local name of *Karaya* gum is *Gulu, Kadaya, Karaya, Katera, Kullo* and *Tapsi*. Chemically, *Karaya* gum is an acid polysaccharide composed of the sugars galactose, rhamnose and galacturonic acid.

Karaya gum has been used commercially for about 100 years. Its use became wide spread during the early 20th century when it was used as an adulteration or alternative to tragacanth gum. Further, *Karaya* gum was less expensive. Traditionally, India is the largest producer and exporter of *Karaya* gum (Gupta *et al.,* 2011). Globally, *Karaya* gum trees are found in South Africa, Australia, Pakistan, Panama, Phillippines, Indonesia, Senegal, Sudan and Vietnam. In India, there are 12 *Karaya* gum species, of four species are available in Andhra Pradesh. They are *S. fotieda, S. populiana, S. vilosa and S. urens.* Only *Sterculia urens* is tap for gum harvesting. In India, producing states are Andhra Pradesh, Maharastra, Gujarat, Orissa, Rajasthan, Karnataka, Bihar and Chhattisgarh. *Karaya* gum trees are commercially found in the forest areas of Dantewada of Chhattisgarh state. Besides this, a few number of *Karaya* gum trees have also been found in Kanker, Jagdalpur, Bijapur, Sukma, Korea and Gariyaband forests (Gupta *et al.,* 2011). In Chhattisgarh, total production of *Karaya* gum was around 19.9 ton during 2012-13. In India, production 1500 tons per annum and 90% of it are exported to Europe and US. Annual world production is estimated at 5500 Tons, while India's share is around 3000 - 3500 tons. It is an important raw material in the textile cosmetic, food, pharmaceutical and other industries (Kuruwanshi *et al.,* 2017).

Karaya gum such an important for forest area (NTFP) of villagers and farmers to raise economical state. The present studies of engineering properties of any material are important from industrial point of view in order to understand the requirement of different process operations for its value addition as well as for its commercial utilization. However, study on physico-chemical and rheological properties of *Karaya* gum (*Stericulia urens*) are focused in present piece of work.

Collection of materials

The sample was collected from Network Project on Harvesting, Processing and Value Addition of Natural Resin and Gums (Fig. 1).

Materials and Methods

Experiment site

The work was carried out in Dr. R. H. Richhariya Research laboratory and Department of Agricultural Processing and Food Engineering, Swami Vivekananda College of Agricultural Engineering and Technology and Research Station, Faculty of Agricultural Engineering, Department of Plant Physiology, College of Agriculture, Indira Gandhi Krishi Vishwa Vidhyalaya, Raipur (Chhattisgarh).

Moisture content

The moisture content of *Karaya* gum was determined by the method described by AOAC (1984). A clean crucible was dried in an air oven at 1050C, 25 and cooled in a desiccator and weighed. Two grams (2.0 g) of finely ground sample was accurately weighed and transferred into crucible. The crucible containing the sample was dried in an oven and weighed regularly till constant weight (Shekarforous *et al.*, 2015). The moisture content was calculated using the following expression:

$$MC = \frac{W_m}{W_m + W_a} \times 100$$

Where, W_m = wt of moisture (g), W_a = weight of bone dry material, (g)

Bulk density

Bulk density of powder was determined by using measuring cylinder. Density can be calculated as weight of the powder divided by the volume acquired by that weighed powder. The SI unit of density is g/cm^3 (Yadav *et al.*, 2015).

True density

Among the various methods available for the determination of true density, the liquid displacement method is the simplest method and was used in the present study (Farooq *et al.*, 2014).

Tap density

The difference between the bulk density and tap density is only that, in bulk density we have to use the bulk volume whereas in the tap density we have to use tap volume which can be obtained by tapings 50 times (Yadav *et al.*, 2015)

Bulkiness

The reciprocal of bulk density is called bulkiness (Yadav *et al.*, 2015). It was calculated by the following equation:

$$\text{Bulkiness} = \frac{1}{\text{bulk density}}$$

Porosity

The porosity may be defined as the ratio of difference between true density and bulk density of grits and true density. According to Mohsenin (1978), porosity (ε) can be expressed as follows (Fos'hat *et al.*, 2011):

$$\varepsilon = \left(1 - \frac{\rho_b}{\rho_t}\right) \times 100$$

where, ρ_b = bulk density, g/cm^3 ρ_t = true density, g/ cm^3

Hausner's ratio

It may be defined as ratio of tap density and bulk density (Yadav *et al.*, 2015).

$$\text{Hausner Ratio} = \frac{\text{Tap density}}{\text{Bulk density}}$$

Carr's compressibility index

The Carr's Compressibility index was determined using following formula (Yadav *et al.*, 2015):

$$\text{Carr's Compressibility Index} = \frac{\text{Tap density} - \text{Bulk density}}{\text{Tap density}}$$

Angle of repose

This apparatus consists of a circular platform immersed in a box filled with *Karaya* gum grits and glass window in one side. The platform is supported by three adjustable screw legs and is surrounded by a metal funnel leading to a discharge hole. The grits allow escaping from the box, leaving the free standing cone of grits on the platform. The angle of repose was determined using the standard procedure and calculation was carried out using following formula (Yadav *et al., 2015*): $\theta = \tan^{-1}\frac{h}{r}$ where, θ = angle of repose (°), h = height (cm), r = radius of circular plate (cm)

Coefficient of friction

The static coefficient of friction of *Karaya* gum grits was measured for four frictional surfaces, namely glass, rubber, plywood, and mild steel. A fiberglass topless and bottomless box of 0.15 m length, 0.10 m width, and 0.04 m height was placed on an adjustable inclined plane, faced with the test surface and filled with the sample. The box was raised slightly (5–10 mm), so as not to touch the surface. The structural surface with the box resting on it was inclined gradually with a screw device until the box just started to slide down over the surface and the angle of tilt (α) was read from a graduated scale (Razavi *et al.*, 2006). The static coefficient of friction (μ_s) was then calculated from the following equation (Mohsenin, 1978): $\mu_s = \tan\alpha$

Ash content

5g of gum 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 % ratio of the mass of the ash to the oven dry mass (Yusuf, 2011).

Determination of pH

The sample powder was thoroughly mixed and 1 g and was dissolved in 100 ml of hot distilled water. The mixture was allowed to stand for 5 min at room temperature before the pH and temperature was recorded using a pre-calibrated pH meter (Ameh, 2012).

Water holding capacity

One g powder of gum *Karaya* was suspended in 10 ml of distilled water, vortexes for 2 min and then centrifuged with a refrigerated centrifuge 3-18 K at 3,000 g for 30 min. Water holding capacity (WHC) was calculated based on the following equation (Mirhosseini and Amid, 2012):

WHC = (SSW-SW)/SW

Where, SSW = water swollen sample weight (g), SW = sample weight (g)

Determination of water sorption

In order to determine the water sorption capacity of the gum, dried evaporating dishes were weighed and 2.0 g of each of the gum samples was weighed into the different dishes. The final weight of the dishes was noted and placed over water in desiccators. After 5 days, the dish was transferred to other desiccators over activated silica gel (desiccant) for another 5 days. The percentage sorption was calculated by difference in weight (Eddy *et al.*, 2012).

Refractive index

Refractive Index of sample was dimensionless number and it can provide information for us about the behavior of light. Refractive index of gum samples was measured in a filtered 1% aqueous solution using a digital refractometer (El – Kheir *et al.*, 2008).

Water activity

Water activity (a_w) was determined using a AquaLab Lite water activity meter at room temperature (García-Cruz *et al.*, 2012).

Determination of solubility

The solubility of the gum was determined in cold and hot distilled water, acetone, chloroform, and ethanol. 1.0 g sample of the gum was added to 50 ml of each of the above mentioned solvents and left overnight. 25 mL of the clear supernatants were taken in small pre-weighted evaporating dishes and heated to dryness over a digital thermostatic water bath. The weights of the residue with reference to the volume of the solutions were determined using a digital top loading balance and expressed as the percentage solubility of the gums in the solvents (Eddy *et al.,* 2012).

Nitrogen and protein content

Nitrogen was determined by semi-micro Khjedal methods (AOAC, 1990). Protein content was calculated using a nitrogen-conversion factor of 6.6 (Yusuf *et al.,* 2011).

$$N\% = \frac{(\text{Volume of sulphonic acid} - \text{Volume of blank}) \times 14 \times \text{Nomality (N)} \times 100}{\text{sample weight} \times 1000}$$

$$P\% = N\% \times 6.6$$

Viscosity measurement

The viscosity was determined and calculated for the 1% solution of the mucilage at 30°C temperature and various rotational speeds by using spindle 63 of digital Brookfield DV-E viscometer (Yadav *et al.,* 2015).

Results and Discussion

Table 1 and 2 shows some of the physicochemical parameters of *Karaya* gum. Food moisture analysis plays a significant role in the modern world. The moisture content of *Karaya* gum was low, suggesting its suitability in formulations containing moisture sensitive foodstuff. It is important to investigate the moisture content of a material because the economic importance of an food for industrial application lies not only on the cheap and ready availability of the biomaterial but the optimization of production processes such as drying, packaging and storage.

Ash values reflect the level of adulteration or handling of the foodstuff. Adulteration by sand or earth is immediately detected as the total ash is normally composed of inorganic mixtures of carbonates, phosphates, silicates and silica. Therefore, the low values of total ash obtained in this study indicate low levels of contamination during gathering and handling of crude *Sterculia urens.*

The bulk and tap densities observed and shown in table 1 it give an insight on the packing and arrangement of the particles and the compaction profile of a material. The Houser's ratio, compressibility Index and angle of repose of *Karaya* gum were 1.14%, 12.31% and 47.27° respectively, implying that the *Karaya* gum has a good flow with moderate compressibility. It is important in scale up processes involving this material as an excipient in a pharmaceutical formulation, cosmetic and food beverages. Modification of formulations containing this gum for the improvement of flow properties during process development will therefore be minimal compared to GA (e.g., inclusion of glidants or agents to aid in feeding). Porosity value of *Karaya* gum powder shown in table 1 is 46.76% it indicated that the number of voids in the sample is minimum it present low air space. Coefficient of friction of *Karaya* gum determined in four different surfaces like glass, mild steel, plywood and rubber and its average observation indicates that the friction is critical to ensuring reliable flow. In rubber surface highest coefficient of friction and followed mild steel, plywood and glass surfaces.

Water activity of gum Karaya was measured at room temperature and result obtained was 0.651 (Table 2). It is a critical factor affecting the shelf life of the product which controlling the behavior for intermediate and low moisture food during processing and storage. The Karaya gum is soluble in water and practically insoluble in ethanol, acetone and chloroform but higher solubility in hot water it indicating that the solubility of the gum is temperature dependent. Since solubility is expected to increase with increase in temperature, the solubility of the gum in hot water is higher than the corresponding solubility in cold water. On the other hand, the samples were not soluble in acetone and chloroform but sparingly soluble in ethanol (Ameh, 2012). The good solubility of these gums is also indicative of the absence of cross linking between polymeric chains. This is because gums having cross linked polymeric chains only swell in water, without dissolving (Yusuf, 2011). The water sorption capacity was calculated and result obtained is 0.885% (Table 2). The water sorption of gum Karaya was increased continue up to the fifth day of immersion (i.e., 100% RH over water) and dropped sharply within 24 hours when subjected to action of desiccant. By the fifth day desiccant environment, water content of gums had reduced considerably 1-3%. It is indicated that if the gum are stored in a damp environment, the gums will quickly be hydrated and also have the tendency to rapidly loose such water molecules in the presence of desiccants (within five days). The observed result is consistent with the findings of Eddy *et al.,* (2012).

Table.1 Physical properties of gum Karaya

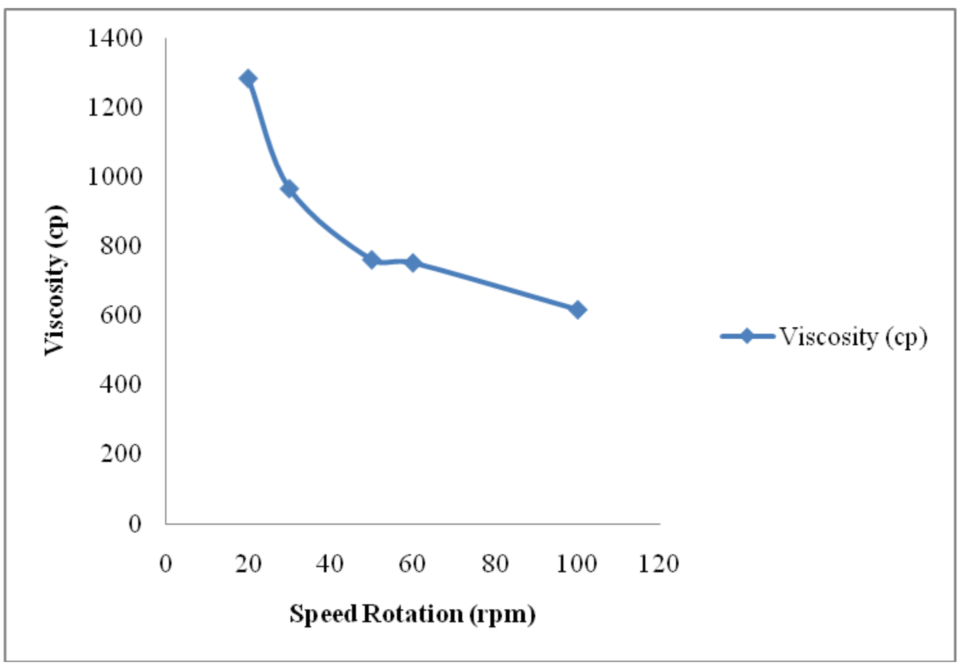
Physical parameters		Results
Moisture Content (%wb)		17.47±0.44
Bulk density (g/ml)		0.79±0.02
True density (g/ml)		1.50±0.17
Tapped density (g/ml)		0.90±0.04
Bulkiness (ml/g)		1.26±0.03
Porosity (%)		46.76±6.12
Hausner's Ratio		1.14±0.06
Carr's Compressibility Index (%)		12.31±4.19
Angle of repose (°)		47.27±2.91
Coefficient of friction (N)		
	Glass	0.24±0.03
	Mild Steel	0.43±0.04
	Plywood	0.28±0.01
	Rubber	0.47±0.04

Table.2 Physicochemical properties of gum Karaya

Physicochemical Parameters		Result
Ash Content (%)		4.62
pH		4.26
Refractive Index		1.336
Water Activity		0.651
Solubility (per 100 ml)		
	Hot Water	27.22
	Cold Water	9.84
	Acetone	0.00
	Chloroform	0.00
	Ethanol	0.00
Water Sorption Capacity (%)		0.89
Water Holding Capacity (per 100 ml)		84.76
Nitrogen (%)		0.16
Protein (%)		1.06

Fig.1 (a) Karaya gum lumps (b) Karaya gum grits (c) Map of potential area (d) Karaya gum tree

Fig.2 Viscosity (cp) versus speed rotation (rpm)



The pH value of Karaya gum shows low acidic nature the pH value of 4.5 is in good agreement with reported pH values for gum Arabic and other Acacia gums by several authors and refractive Index value 1.336 is similar to those reported by Taha *et al.*, (2009), Ahmed *et al.*, (2009) and El-kheir *et al.*,(2008). Water holding capacity value shows by analysis about 84.76% is nearly according to Taha *et al.*, (2012) for three types of gum from Sudan and Ahmed *et al.*, (2009) for *Anogeissus leiocarpus* gum. Nitrogen and protein content value is almost similar by authors Elkhalifa and Hassan (2010) and Adeleye *et al.*, (2015). Figure 2 shows the plot of viscosity versus the rotation speed at 1% concentration of gum solution. From Figure 2 it was observed that the viscosity of gum decrease with increase in speed of rotation (rpm). The values of viscosity were obtained 1286, 968, 763, 754 and 619 cp for rotational speed 20, 30, 50, 60 and 100 rpm. Gum Karaya gives rise to high-viscosity solutions even at 1% concentration.

In conclusion, the quality and applicability of well characterized materials are directly related to their physical and chemical properties. The results of this study support the gum suitability for industrial application, especially in areas where commercial *Karaya* gum is traditionally used. The physicochemical profile of the *Karaya* gum sample studied and the wide availability of the raw materials in Chhattisgarh State and other States. The results obtained in this study established for the first time, the fundamental characteristics of *Karaya* gum. The present investigation is a primary platform to indicate the suitability of *Karaya* gum as a binding agent.

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