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Nutritional, physical and thermal properties of *Cassia tora* (Charota) seeds

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Abstract
In this study, we conducted a comprehensive analysis of the nutritional, physical, and thermal properties of charota seeds (*Cassia tora*). The seeds were found to consist of three main components: husk (16.83%), endosperm (40.67%), and gum layer (42.50%). On average, the charota seeds measured 0.612 mm in size and contained 4.44% ash, 9.25% fat, 28.13% fiber, 23.44% protein, and 25.68% carbohydrates at a moisture content of 10.82% (wb). Notably, charota seeds were rich in calcium, phosphorus, and iron. The seeds exhibited specific physical characteristics, including a length of 4.57 mm, width of 1.90 mm, thickness of 1.76 mm, arithmetic mean diameter of 2.74 mm, geometric mean diameter of 2.47 mm, thousand seed weight of 14.77 g, volume of 22.745 mm^3, sphericity of 0.559, surface area of 17.04 mm^2, and aspect ratio of 42.06. Additionally, the seeds had a true density of 921.33 kg/m^3, bulk density of 816.06 kg/m^3, porosity of 11.43%, and an angle of repose of 40.02°. In terms of friction characteristics, charota seeds exhibited higher friction on plywood surfaces, followed by rubber, mild steel, and glass surfaces. Moreover, the thermal properties of charota seeds included a thermal conductivity of 0.0663 $W.m^{-1}.K^{-1}$ and a resistivity of 0.00155 °C cm/W.

Keywords: Charota seed, physical properties, thermal properties

1. Introduction

Medicinal plants and plants-derived medicines are widely used in traditional cultures worldwide, and due to natural harmony their popularity is increasing in modern the world as natural alternatives or supplements to replace the synthetic (chemical) preparations (Wyk and Wink, 2017) [61]. Plants in general contribute to the mineral, vitamin and fiber contents of human diets. Among the plants, vegetables are excellent source of minerals and contribute to the recommended dietary allowance (RDA) of these essential nutrients (Shaikh and Zainuddin Syed, 2016) [47]. Plants provide food, medicine, clothes, shelter and the raw materials from which in numerable other products are also made. Thus, plants are an essential natural resource for human existence. The use and adoption of herbal medicines dates back several thousand years to the Rig-Veda which led to a system of health care known as Ayurvedic system of medicine particularly in Indian subcontinents (Farah *et. al.*, 2011) [24].

Cassia tora is a local naturally growing annual weed/shrub available in different parts of the country and known by vernacular names as Ponwar (Hindi); Tarota (Marathi); Charota (Chhattisgarhi); Foetid Cassia (English); *Jui ming Zi* (Chinese); Chakramard (Ayurveda). It belongs to the family of *Caesalpiniaceae* (Jain and Patil, 2010) [31]. Its different species are also found in different parts of the world having tropical and sub-tropical climates. The charota of various species are widely grown in Asian Countries (Peng *et al.*, 2022) [43]. Its existence has also been seen in high hills elevation up to 1800 meters along with the plain areas. It is a legumenous plant bears the seeds in the pods; the dried seeds are used for making traditional drinks or used in the preparation of folk medicines by the traditional healers. The seeds of charota are reported to have the characteristics of improving eyesight, alleviating constipation, and lowering hypertension and hyperlipidemia (Deore and Mahajan, 2018) [19]. The charota seed is composed of hull (27%), endosperm (32%), and germ (41%) reported in the literature Pawar and Lalitha (2015) [42]. Seeds of charota contain about 23.2% of proteins, rich in all essential amino acids, particularly, methionine and tryptophan. The charota plant is contains around 1-2% of oil and smells like a spicy aroma, and ameliorates the food taste (Altrafine gum, 2021-22) [4].

The plant is an annual herbaceous herb, almost like shrub, height up to 30-90 cm, with pinnate leaves. Leaflets are in 3 pairs, opposite, obovate, oblong with oblique base and elongate up to 10 cm. Flowers are seen as pale yellow in colour and pair in axils of leaves with five petals.

Blooming of charota is favorable after the rainy season of monsoon. Pods of charota are curve shape like sickle, 10 to 15 cm tall and, flattened or four angled, hence, it is called as sickle-pod. The number of seeds is 30-50 in a pod, hexagonal lattice in each layer (Jain and Patil, 2010) [31]. Seeds are oblong shaped, 3-5 mm long, 2-3 mm in diameter, pointed at one edge and at the other end rounded or truncate. In addition, its colour looks like deep-brown, smooth surface and glossy nature. The seeds are gelatinous and bitter in taste (WHO, 1989) [59].

The demand of charota seed has been increased in recent years due to its use in the different industrial applications. The flash price of charota seed currently has been observed to be varied from Rs. 4000.00 to 5000.00 for per 100 kg (Sonwani *et al.*, 2018) [52]. In Chhattisgarh, its availability is found abundantly in rural areas of Bastar, Bilaspur, Durg, and Sarguja districts. Sarguja district only accounts for more than 60% of the charota production in the State (Sonwani *et al*., 2018) [52]. Though the collection of charota seed is not well organized in the state and country, however, according an estimate of Chhattisgarh State Medicinal Plant Board (CGSMPB), the annual production in Chhattishgarh is the highest in the country with a total collection of 5000 MT (Satish Chandra, 2017) [15]. Thus, the charota plant and seed play an important place in the state while considering the income and livelihood generation in addition to medicinal benefits.

The fruit of self-grown charota is a precious gift for the landless villagers and the tribal communities because it used in the preparation of various medicines and traditional healers use the parts of this important of plant since unknown times.

Cassia tora seeds find application in the formulation of numerous Ayurvedic remedies, green tea, and even ice cream. Local residents gather these seeds, which are subsequently sold to traders via intermediaries and village-level entrepreneurs. While the extensive collection and trade of these seeds occur within the region, there appears to be a lack of well-documented or complete information regarding their organized industrial utilization. Throughout history, various parts of *Cassia tora* plants, including leaves, seeds, and roots, have been extensively utilized in medicinal preparations to address a range of ailments. Notably, the seeds are a key component in Chinese medicine, serving as aperients, anti-asthenic, and diuretic agents. They have been harnessed to enhance visual function and treat liver disorders. Korean therapy has incorporated seed extract for oral consumption. These seeds are effective in mitigating liver-related heat, enhancing eyesight, and alleviating constipation. They have also proven beneficial for eye diseases, liver issues, earache, leprosy, and psoriasis (Farah *et al.,* 2011) [24]. Chinese healers have embraced this herb, achieving success in treating blindness, xerophthalmia, and conjunctivitis. The seeds additionally contribute to lowering cholesterol and blood pressure, while the unripe fruits find culinary use after cooking. There's potential for the seeds to bolster livestock nutrition and even serve as a protein-rich ingredient in food preparation. They can also yield flavorful sweets and a coffee substitute when ground and roasted. Furthermore, these seeds possess dyeing and tanning properties, yielding yellow, blue, and red hues (Singh *et al*., 2013; Bhandirge *et al*., 2016) [49, 12].

The comprehension of nutritional, physical and thermal properties associated with *Cassia tora* seeds holds significant relevance in devising machinery for their collection, transportation, cleansing, segregation, packaging, storage, and conversion into diverse food products. Despite its pivotal role in various processing stages and value augmentation, the scientific literature lacks insights into the physico-chemical and thermal traits of *Cassia tora* seeds. Acquiring knowledge about these attributes stands as a fundamental necessity for optimizing unit operations, value addition processes, and overall processing efficiency. Consequently, the meticulous analysis and incorporation of these properties assume a crucial role in the strategic design of related equipment. Moreover, these inherent physical characteristics wield substantial influence over the conveyance behaviors of solid materials via mediums such as air or water, alongside regulating the thermal dynamics involved in cooling and heating processes of food materials.

A specific knowledge of the *Cassia tora* seed nutritional, physical and thermal properties such as proximate analysis, minerals, linear dimensions, arithmetic mean and geometric mean diameter, sphericity, surface area, aspect ratio, true and bulk density, porosity, volume, angle of repose, coefficient of friction, thermal conductivity and resistivity *etc*. and the differences between the properties of fruit is necessary to design of *Cassia tora* seed processing equipment.

The operational performance of various machinery is profoundly influenced by the dimensions and configuration of the involved seeds. Therefore, for an effective analysis of a specific process, it is imperative to provide a precise description of the fruit. The nutritional attributes of seeds assume a pivotal role in enhancing value and fortification of food products. Parameters like size, shape, projected area, and porosity of the seed hold paramount significance, particularly in the context of packaging, dimensions after packing, and related considerations. Notably, sphericity emerges as a critical characteristic due to its profound impact on the processing feasibility of *Cassia tora* within the food industry. Furthermore, the volume and density of seeds exert a substantial influence on a multitude of technological processes and hold relevance in gauging product quality. Another crucial factor is the coefficient of static friction, which significantly affects the transportation (loading and unloading) of goods and storage arrangements.

Many studies have been reported on the nutritional, physical and thermal properties of seeds such as cowpea seeds (Kabas *et al.,* 2007) [32], *Cassia tora* L. seed powder (Kamble and Deshmukh, 2020) [33], *Cassia fistula* seeds (Akinyede and Amoo, 2009) [2-3], *Cassia Tora* seeds (Assam *et al.,* 2019) [9], guar seeds (Eldirany *et al.,* 2015) [22], *Cassia occidentalis* seeds (Ezekiel *et al.,* 2019) [23], Wheat (Tabatabaeefar, 2003) [53], Lentil seeds (Amin *et al*., 2004) [6], Safflower seed (Baumler *et al.,* 2006) [11], Pomegranate seeds (Kingsly *et al.*, 2006) [35], Cucurbit seeds (Milani *et al.,* 2007) [37], Karanja kernel (Pradhan *et al.,* 2008) [44], Jatropha seeds (Garnayak *et al.,* 2008) [25], Chia seeds (Ixtaina *et al.,* 2008) [29], Barley (Sologubik *et al.,* 2013) [50], Lathyrus (Kenghe *et al.,* 2013) [34], roselle seeds (Bamgboye and Adejumo, 2010) [10] and Sunflower seeds (Gupta *et al.,*1996) but no detailed study concerning physical properties of *Cassia tora* seeds have been performed.

2. Material and Methods

2.1 Raw Material

Fresh charota seed sample was procured from the local market of Bhanpuri, Raipur (CG) to use in the experiment. The raw seed obtained was cleaned manually to get out rid of dust, dirt and other foreign materials by using sieving followed by grading. The undesirable and undeveloped seeds were removed manually to maintain the uniformity of the sample to be used in the experiments. The moisture content of the seed sample at the time was procurement was determined to be 9.97% (db). The cleaned seeds were then packaged in polyethylene bags and stored in a dry and cool place for further use.

2.2 Sieve Analysis of Charota Seeds
In order to determine the average size of charota seeds, the seed samples were subjected to screen analysis using Indian Standard Screens set (BSS standard) by Gyratory sieve shaker machine and shaked for 5 min. The fineness modulus (FM) was calculated following the standard procedure. The average particle size (D_p) was calculated using the following relationship described by Sahay and Singh, 2009 (Eqn. 3.1).

$$D_p = 0.135\,(1.366)^{FM} \quad (1)$$

Where, FM is the fineness modulus and D_p is the average particle size.

2.3 Composition of Charota Seed
The composition of charota seed parts (fractions of different parts) was determined following the procedure described by El-Daw (1998) [21] with some modification. 50 sound seeds were weighed accurately and soaked in 100 ml distilled water for overnight (10 -12 h). The soaked seeds were taken out from the water and wiped with blotting paper to dry the surface moisture. Different fractions or the components of the seeds were separated manually in to hulls/husk, endosperm with germ and gum layer. These components were dried in a hot air oven at 40 °C temperature till constant weight. Each part (hull/husk, endosperm and gum layers) was weighed separately and calculated the share of each component.

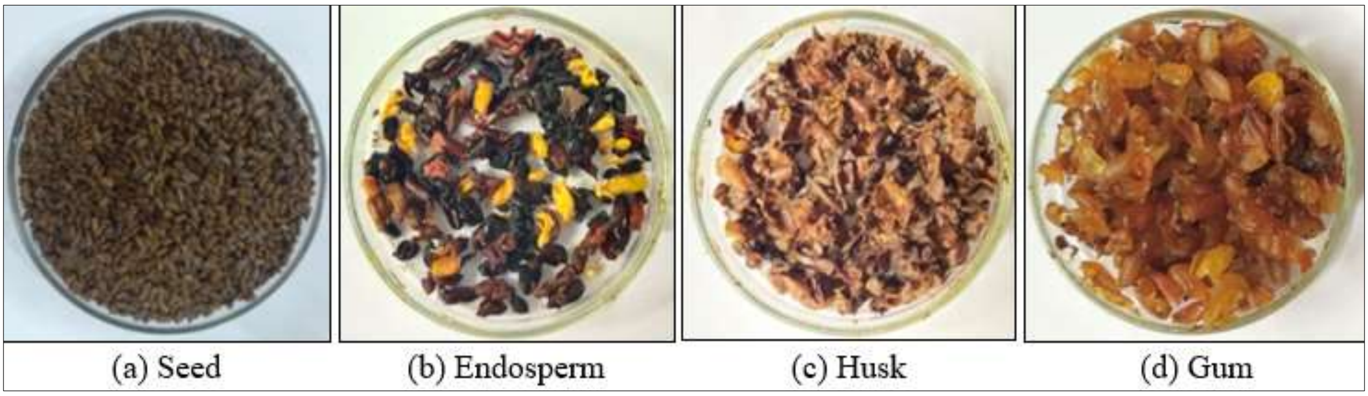

Fig 1: Component of charota seed

2.4 Proximate analysis
Moisture content (MC) of charota seeds was determined by drying the sample in a convection hot air oven (Make - Esteem Industries Inc., Model – ESTO 111) at 105±1 °C following the method described by Gharib-Zahedi *et al.* (2010) [26]; AOAC (2010) [8]. Ash content of charota seeds was determined by using a muffle furnace (EXACTA FURNACE, New Delhi) (AOAC, 2010) [8]. Protein content (P) of seed sample was determined by assessing nitrogen content (N) in samples using Kjedhal method (AOAC, 2010) [8]. The process involved three steps *i.e.* digestion, distillation and titration. All the steps were accomplished following the standard procedures described. To obtained protein content, nitrogen-protein conversion factor of 6.25 was used for plant materials. The nitrogen and protein contents were calculated by the following equations (Eqn. 1 and 2).

$$N\,(\%) = \frac{14 \times N \times (V_b - V_s) \times 100}{W_s \times 100} \quad (2)$$

$$P\,(\%) = N\,(\%) \times 6.25 \quad (3)$$

Where, N is the normality of acid (0.1N), V_b is the volume of blank (mL), V_s is the volume of sample (mL) and W_s is the initial weight of the sample (g). Total carbohydrate content of seed was determined by the anthrone method (Chelladurai *et al.*, 2019) [16]. Calculation of total carbohydrate (CHO) present in sample was done by following formula (Eqn. 3.6).

$$CHO\,(\%) = \frac{S_v}{S} \times \frac{V_t}{W_s} \times 100 \quad (4)$$

Where, S_v is the sugar value from graph in mg, S is the aliquot sample used, (0.5/1) mL, W_s is the weight of sample in mg and V_t is the total volume of extract in mL.

Fat content of charota seed was determined by SOCS PLUS apparatus (Pelican Equipments Chennai, Model: SCS-4) using n-hexane as a solvent for 2 - 3 h according to a described procedure detailed in AOAC (2010) [8]. According to the procedure mentioned in AOAC (2010) [8], the fiber content in seed sample was determined by FIBRA PLUS apparatus (Pelican Equipments Chennai) using H_2SO_4 as acid digestion and NaOH as alkali digestion.

2.5 Mineral contents
Iron, phosphorus and calcium content of charota seed were determined following the standard procedures (Paul *et al.*, 2017; Jackson, 1973) [40, 30]. Mineral ions were detected after the digestion of the specimen using di-acid mixture (HNO_3:$HClO_4$::9:4).

2.6 Physical properties
The average size was determined based on 100 randomly selected seeds (Zewdu and Solomon, 2007) [62]. The length (L), width (W) and thickness (T) of sample seeds were measured using a digital caliper with an accuracy of 0.01 mm (Tavakoli *et al.*, 2009, Pradhan *et al.*, 2008 [54, 44],

Tabatabaeefar, 2003) [53]. The average diameter of seeds was calculated using the arithmetic mean and geometric mean of the three axial dimensions. The arithmetic mean diameter, D_a and geometric mean diameter, D_g of the seeds were calculated by using the following relationships (Mohsenin, 1970) [38]:

$$D_a = \frac{L+W+T}{3} \quad (5)$$

$$D_g = (LWT)^{1/3} \quad (6)$$

The sphericity $\emptyset$, of charota seeds was calculated by using the following relationship (Mohsenin, 1970) [38]:

$$\emptyset = \frac{(LWT)^{1/3}}{L} \quad (7)$$

The surface area of charota seeds found by analogy with a sphere of the same geometric mean diameter, using the following relationship (Pradhan *et al.*, 2008, Garnayak *et al.*, 2008, Ixtaina *et al.*, 2008) [44, 25, 29]:

$$S = \pi D_g^2 \quad (8)$$

Aspect ratio(R) was calculated (Ixtaina *et al.*, 2008) [29] as:

$$R = \frac{W}{L} \times 100 \quad (9)$$

The thousand grain weight was determined randomly selecting100 seed of the overall sample, measuring their weight on a digital electronic balance with an accuracy of 0.0001 g and multiplying by10 to get the mass of 1000 seeds (Sologubik *et al.*, 2013) [50]. The bulk density was determined using the mass/volume relationship, by filling an empty plastic container of predetermined volume and tare weight with the seeds by pouring from a constant height, striking off the top level and weighing (Tavakoli *et al.*, 2009) [54]. The true density defined as the ratio between the mass of charota seed and true volume of seed was determined using the toluene (C_7H_8) displacement method (Sacilik *et al*., 2003) [46]. The porosity of bulk seed was calculated from bulk and true densities using the relationship (Garnayak *et al.*, 2008 and Mohsenin, 1970) [25, 38], as follows:

$$\rho = \left(1 - \frac{\rho_b}{\rho_t}\right) \times 100 \quad (10)$$

Where, ε is the porosity (%), ρ_b the bulk density (kg m^{-3}) and ρ_t is the true density (kg m^{-3}).
The volume (V_g) of seeds (mm^3) was determined from the following relationship (Baumler *et al*., 2006) [11].

$$V_g = \left({}^{m}/_{\rho_t} \right) 10^3 \; () \quad (11)$$

Where, m is the unit mass of the seed (in kg) determined from samples used to calculate the true density.
The angle of repose is the angle between the base and slope of the cone formed on a free vertical fall of the granular material (Kenghe *et al.*, 2013) [34]. The angle of repose θ was calculated using the formula (Pradhan *et al.*, 2008) [44].

$$\theta = \tan^{-1} \frac{2H}{D} \quad (12)$$

Where, H is the height of the cone in cm and D is the diameter of cone in cm.
The coefficients of friction of charota seeds were determined on the surfaces *viz.*, rubber, mild steel, plywood, and glass sheet. The method used by Amin *et al.* (2004) [6] was used to determine the coefficient of friction of charota seeds. The coefficient of friction, μ was calculated using the following formula (Eqn. 3.16).

$$\mu = \frac{F}{W} \quad (13)$$

Where, F = force required just to move the box with a slight push and W = weight of box plus seed.

2.7 Thermal Properties
Thermal conductivity and resistivity of charota seeds were determined with the help of a thermal analyzer (TEMPOS thermal analyzer, METER Group Inc. USA) using TR-3 probe supplied with the instrument.

3. Result and Discussion
3.1 Seed composition
The fractional analysis of charota seeds was done to determine the composition of seeds. It was found that seeds were composed of husk, endosperm and gum layer and their proportions were determined as 16.83%, 40.67% and 42.50%, respectively. The gum layer part of the seed is dominanted by protein and the endosperm is predominantly galactomannan. Seed galactomannans are important agro-chemicals used in various industries worldwide (Amin *et al.*, 2007) [5]. Galactomannans are natural polysaccharides composed of a linear mannan backbone bearing side chains of single galactose residues. The structure of seed is a linear chain of 1, 4-β-D-mannopyranose units and 1, 6 linked α-D-galactopyranose units (Cao *et al.*, 2018) [14]. Similar observation was reported by El-Dawa (1998) [21] for the gaur seed component and slight difference was recorded by Pawar and Dmello (2011a) [41] and Meena *et al.* (2010) [36] on *Cassia tora* seeds.

3.2 Particle size distribution
The average particle size distribution of agricultural materials largely influences the flow ability of material during different unit operations like handling, conveying, and processing. Also, the particle size of seed influences the drag coefficient that greatly affects the design parameters and internal angle of friction during design of various equipments like sieve, hopper, silos *etc*. The particle size of charota seed was determined to correlate the flow behavior of the seed under different conditions during various machine operations. The average size of charota seed was found to be 0.612 mm and shown in Table 1. The maximum percent of seed was retained on the BSS-10 sieve size and minimum by BSS-18 sieve size. A log-log plot between percent finer than screen opening is depicted in Fig. 2.

Table 1: Sieve analysis of charota seed

S. No.	BSS identification No.	Width of opening, mm	Weight of seed retained, g	Seed retained, %	Weight fraction of retained material	Fineness modulus (FM)	Average particle size, mm
1.	8	2.032	0.0	0.0	0.0		
2.	10	1.676	442.6	88.52	442.6		
3.	12	1.405	36.6	7.32	29.28	4.84	0.612
4.	14	1.201	16.4	3.28	9.84		
5.	18	0.954	7.0	1.4	2.8		
6.	22	0.708	0.0	0.0	0.0		
	Pan		0.0	0.0	0.0		
Total					484.52		

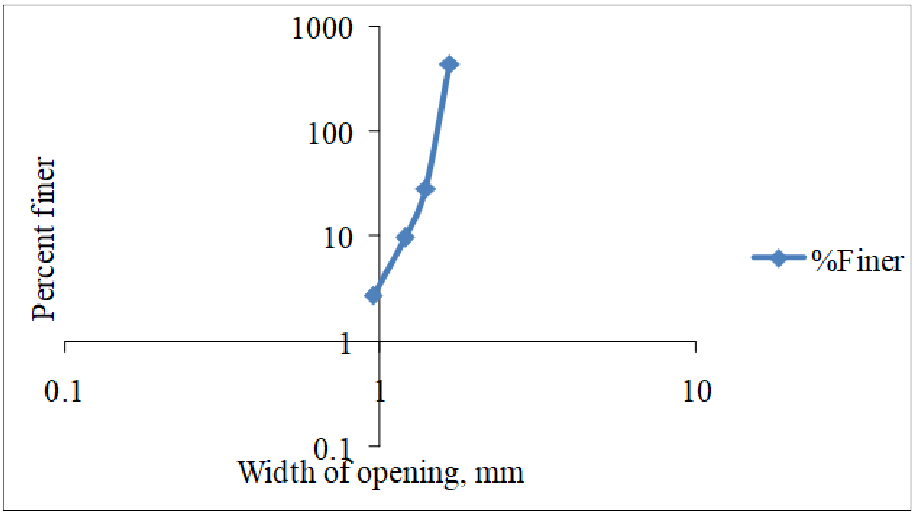

Fig. 2: Log-log plot of percent finer than the screen size of sieve

The relationship between percent finer than and screen size of sieve was appeared to be linear and could be expressed by the following equation (Eqn. 14).

$$Y = 579.5 X - 637.4, (R^2 = 0.684) \quad (14)$$

Where, X is the width of opening (mm) and Y is the percent finer than.

3.3 Proximate analysis of charota seed

The result of the proximate analyses of charota seed is summarized in Table 2. The charota seed sample at 10.82% (wb) moisture content contained on an average 4.44% ash, 9.25% fat, 28.13% fiber, 23.44% protein and 25.68% carbohydrate. The results are the mean of three determinations.

Ash content was observed to be nearly equal to the values reported for *Cassia tora* (Adamu *et al*., 2013) [1] and *Cassia alata* seeds (Ukhun and Ifebigh, 1988) [56]. Pawar and D'mello (2011a) [41] reported 23.2% of protein content in *Cassia tora* seed which was rich in all essential amino-acids, particularly, methionine and tryptophan. The findings are observed to be slight different from gaur seed composition (moisture (11.13%), ash (3.49%), protein (29.1%), fat (1.58%), fiber (9.01%), and carbohydrate (45.50%)) as reported by El-Dawa (1998) [21] for three genotypes (HFG53, HFG182 and HFG363). Hrncic *et al*. (2019) [28] reviewed high nutritional properties for chia seed and reported the values of different components as fiber (18-30%), fat (30-33%), carbohydrate (26-41%) and protein (15-25%). Higher protein content has been reported for *Cassia tora*, *Cassia floribunda*, *Cassia hirsuta* L. seeds, Iranian basil seed and fenugreek seed by Adamu *et al*. (2013) [1], Vadivel and Janardhanan (2001) [58], Vadivel and Janardhanan (2000) [57], Razavi *et al.* (2009) [45] and Brummer *et al.* (2003) [13], respectively as compared to the charota seeds under study.

Olpade *et al.* (2014) [39] reported moderately high contents of crude protein (23.72%) and crude fibre (10.75%) for *Cassia sieberiana* seeds. The crude fiber of *Cassia occidentalis* seed was recorded to be 16.30% by Willims *et al.* (2019). It is well known that chemical compositions of seeds depend on the variety and the differences in climatic conditions and soil conditions as well where the plants are grown.

Table 2: Proximate composition of charota seed

S. No.	Component	Value (%)
1.	Moisture content (wb)	10.82 ± 0.10
2.	Fat content	9.25 ± 1.57
3.	Carbohydrate	25.68 ± 0.22
4.	Ash content	4.44 ± 0.30
5.	Fiber	28.13 ± 1.88
6.	Protein	23.44 ± 1.87

3.4 Mineral content of charota seed

The major mineral contents in charota seeds were determined and Table 3 gives the values of major mineral contents in mg per 100 g of seeds. Charota seed was found to be higher in calcium, phosphorus and iron contents compared to the normal levels of most of the other seeds. Vadivel and Janardhanan (2000) [57] observed lesser contents of calcium, iron and phosphorus in *Cassia hirsuta* L. seeds. The *Cassia obtusifolia* contains higher values of calcium 4100 and 6590 ppm for FSY-1013 and FSY-1034 varieties, respectively (Crawford *et al.*, 1990) [18]. Also, Ukhun and Ifebigh (1988) [56] observed lesser calcium contents in *Cassia alata* seeds as compared to charota seed. Calcium and iron contents of

Cassia tora seed were recorded comparatively lesser by Adamu *et al*. (2013) [1] than the obtained values in the present investigation. Iron and phosphorus in charota seed were found to be higher than the contents in *Cassia floribunda* (Vadivel and Janardhanan, 2001) [58]. Siddhuraja *et al*. (1995) [48] have also reported lesser values of mineral contents in *Cassia laevigata* compared to the observed values.

Table 3: Major mineral contents in charota seed (mg/100g)

S. No.	Minerals	Value
1.	Calcium	630.0
2.	Iron	37.1
3.	Phosphorus	240.0

3.5 Physical and thermal properties of charota seed

Table 4 presents the physical and thermal characteristics of charota seeds, observed at a moisture content of 9.97% (dry basis). The dimensions of the seeds were measured, revealing lengths ranging from 6.13 to 3.41 mm, widths from 2.25 to 1.56 mm, and thicknesses from 2.03 to 1.15 mm. The seeds exhibited varying arithmetic mean diameters of 3.39 to 2.41 mm and geometric mean diameters of 2.92 to 2.12 mm. The weight of a thousand seeds ranged from 14.8001 to 14.7501 g. Additionally, the characteristics describing the shape of charota seeds included sphericity, surface area, volume, and aspect ratio. Sphericity, denoting the similarity of the shape to that of a sphere with the same volume, varied from 0.697 to 0.451. The surface area spanned from 26.84 to 14.06 mm², while the volume ranged between 53.927 and 13.203 mm³. Tunde-Akintunde and Akintunde (2004) reported sphericity values akin to those found in sesame seeds. Similarly, Coskun *et al.* (2006) documented sphericity measurements ranging from 0.615 to 0.635 for sweet corn seeds. The surface area of caper seeds, as reported by Dursun and Dursun (2005), ranged from 15.81 to 23.07 mm², aligning closely with the findings of the current study. The aspect ratio, signifying the relationship between width and length and reflecting the seed's inclination towards an elongated form, ranged from 59.53 to 31.66. This aspect ratio observation was found to be consistent with Kabas *et al.*'s work in 2007 [32].

Table 4: Physical properties of *Cassia tora* seed at 9.97% (db) moisture content

Particulars	Max	Min	Mean	SD
Length, mm	6.13	3.41	4.57	0.50
Width, mm	2.25	1.56	1.90	0.17
Thickness, mm	2.03	1.15	1.76	0.16
Sphericity	0.697	0.451	0.559	0.050
Surface area, mm^2	26.84	14.06	17.04	2.69
Volume, mm^3	53.927	13.203	22.745	7.425
Thousand seed weight, g	14.8001	14.7501	14.77	0.0258
Aspect ratio	59.53	31.66	42.06	5.77
Arithmetic mean diameter, mm	3.39	2.41	2.74	0.20
Geometric mean diameter, mm	2.92	2.12	2.47	0.17
Bulk density, kg/m^3	878.44	793.64	816.06	35.15
True density, kg/m^3	923.11	920.10	921.33	1.58
Porosity, %	11.60	11.31	11.43	0.15
Angle of repose, °	41.35	38.66	40.02	0.95
Coefficient of friction				
Plywood	1.81	1.71	1.75	0.036
Rubber	1.47	1.41	1.44	0.032
Mild steel	1.47	1.41	1.44	0.032
Glass	1.47	1.41	1.45	0.032
Thermal conductivity, $W.m^{-1}.K^{-1}$	0.0735	0.0591	0.0663	0.0101
Thermal resistivity, °C cm/W	0.0014	0.0017	0.00155	0.000212

The seeds of charota exhibited a range of bulk density, which fell between 878.44 and 793.64 kg/m³, while the true density ranged from 923.11 to 920.10 kg/cm³. Notably, the true density consistently surpassed the bulk density of the seeds. This disparity between the two density values contributes to the porosity of the charota seeds, which ranged from 11.60% to 11.31%. It would be noted that the porosity of the bulk seeds described by the resistance to airflow during aeration and drying procedures (Ixtaina *et al.*, 2008) [29]. This trend of higher bulk density compared to true density is in line with Kabas *et al.*'s findings in 2007 [32], who reported a similar observation for cowpea seeds.

The angle of repose for charota seeds was measured to range between 41.35° and 38.66°. This parameter holds significant importance in the design of hopper openings, side wall slopes for storage bins, and the bulk transportation of seeds through chutes. Similar results were documented by Kenghe *et al.* (2013) [34] in their study on lathyrus seeds and by Sologubik *et al.* (2013) [50] for barley seeds.

In terms of friction characteristics, the coefficient of friction exhibited a range of values from 1.81 to 1.71 when tested on plywood surfaces, and from 1.47 to 1.41 on surfaces made of rubber, mild steel, and glass. Notably, the coefficient of friction for the seeds was found to be higher when tested on plywood surfaces. This coefficient of friction parameter holds vital importance in the analysis of silos (deep bins) and the design of equipment used for material handling. A similar trend was observed by Amin *et al.* (2004) [6] and Solomon and Zewdu (2009) [62] in their respective studies on lentil seeds and niger seeds. Their analyses revealed that the static and kinetic coefficients of friction were lowest when interacting with glass surfaces.

The thermal properties of charota seeds were determined using a thermal analyzer. Thermal resistivity, which is the reciprocal of thermal conductivity, was employed. The thermal conductivity of the seeds ranged between 0.0735 to 0.0591 W.m-1.K-1, while the thermal resistivity was found to be within the range of 0.0014 to 0.0017 °C-cm/W.

Conclusion

In summary, charota seeds were found to consist of three main components: husk, endosperm, and gum layer. Through sieve analysis, we determined that the average size of charota seeds was 0.612 mm. These seeds were notably rich in protein, containing 23.44% protein and 25.68% carbohydrates.

Additionally, charota seeds exhibited elevated levels of calcium, phosphorus, and iron compared to typical seed compositions. The thousand-seed weight ranged from 14.8001 to 14.7501 g, and sphericity values varied from 0.697 to 0.451. The seeds' surface area ranged from 26.84 to 14.06 mm^2, with volumes spanning from 53.927 to 13.203 mm^3. The aspect ratio indicated a tendency toward elongated seed forms.

Charota seeds displayed bulk densities lower than their true densities, with porosity levels ranging from 11.60% to 11.31%. The angle of repose for charota seeds fell between 41.35° and 38.66°. Notably, the seeds exhibited higher coefficients of friction on plywood surfaces.

Furthermore, the thermal conductivity of these seeds ranged from 0.0735 to 0.0591 $W.m^{-1}.K^{-1}$, while the thermal resistivity varied from 0.0014 to 0.0017 ^{o}C-cm/W. These findings provide valuable insights into the diverse properties of charota seeds, which can have implications for various applications and industries.

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Reference

1. Adamu HM, Ushie OA, Elisha B. Chemical and nutrient analysis of raw and fermented seeds of *Cassia tora*. Journal of Physical Science and Innovation. 2013;5(1):125-138.
2. Akinyede AI, Amoo IA. Chemical and functional properties of full fat and defatted *Cassia fistula* seed flours. Pak. J Nutr. 2009;8(6):765-769.
3. Akinyede AI, Amoo IA. Chemical and functional properties of full fat and defatted *Cassia fistula* seed flours. Pakistan Journal of Nutrition. 2009;8(6):765-769.
4. Altrafine Gums. 2021-22. (https://www.altrafine.com/blog/application-of-cassia-gum-powder-in-beverages)
5. Amin, Mat A, Ahmad, Shamsuddin A, Yin, Yin Y, Yahya, *et al*. Extraction, purification and characterization of durian (*Durio zibethinus*) seed gum. Food Hydrocolloids. 2007;21:273-279.
6. Amin MN, Hossain MA, Roy KC. Effects of moisture content on some physical properties of lentil seeds. Journal of Food Engineering. 2004;65:83-87.
7. Amin MN, Hossain MA, Roy KC. Effects of moisture content on some physical properties of lentil seeds. Journal of Food Engineering. 2004;65:83-87.
8. AOAC. Official methods of analysis. 18th edition (Revision III), Association of Official Analytical Chemists, Washington DC; c2010. p. 1785.
9. Assam ED, Ndelekwute EK, Demo K, Okonkwo AC, Ukachukwu SN. Effect of boiling on biochemical composition of raw *Cassia Tora* seeds and its potential as feed ingredient in poultry feeds. Nigerian Journal of Animal Science. 2019;21(3):288-293.
10. Bamgboye AI, Adejumo OI. Thermal properties of roselle seeds. International Agrophysics. 2010;24(1):85-87.
11. Baumler, Erica, Cuniberti, Adela, Susana NM, Riccobene, *et al*. Moisture dependent physical and compression properties of safflower seed. Journal of Food Engineering. 2006;72:134-140.
12. Bhandirge SK, Patel V, Patidar A, Pasi A, Sharma V. An overview on phytochemical and pharmacological profile of *Cassia tora* Linn. International Journal of Herbal Meddicine. 2016;4:50-55.
13. Brummer Y, Cui W, Wang Q. Extraction, purification and physicochemical characterization of fenugreek gum. Food Hydrocollids. 2003;17(3):229-236.
14. Cao Lele, Liu, Wenbo, Wang Lijun. Developing a green and edible film from *Cassia* gum: The effects of glycerol and sorbitol. Journal of Cleaner Production. 2018;175:276-282.
15. Chandra, Satish N. Assessment of export potential of medicinal plants and its derivatives from Chhattisgarh and its policy implications. Chhattisgarh State Medicinal Plants Board (CGSMPB) Raipur, Chhattisgarh; c2017. p. 1-187.
16. Chelladurai, Chellamboli, Pandey, Ayushi A, Panmand, Sonal A, *et al.* Development of innovative bakery product chia seed enriched cookies. International Journal of Food Science and Nutrition. 2019;4(2):19-23.
17. Coşkun MB, Yalçın İ, Özarslan C. Physical properties of sweet corn seed (*Zea mays saccharata* Sturt.). Journal of Food Engineering. 2006;74(4):523-528.
18. Crawford L, McDonald GM, Friedman M. Composition of sicklepod (*Cassia obtusifolia*) toxic weed seeds. Journal of Agricultural and Food Chemistry. 1990;38(12):2169-2175.
19. Deore UV, Mahajan HS. Isolation and characterization of natural polysaccharide from *Cassia obtustifolia* seed mucilage as film forming material for drug delivery. International Journal of Biological Macromolecules. 2018;115(2018):1071-1078.
20. Dursun E, Dursun I. Some physical properties of caper seed. Biosystems Engineering. 2005;92(2):237-245.
21. El-Dawa, Ganal El-Awad. Study of guar seed amd guar gum properties (*Cyamopsis tetragonolabous*). B.Sc (agric.) honours (thesis) 1994, Faculty of Agriculture, University of Khartoum; c1998.
22. Eldirany AA, Nour AA, Khadir KI, Gadeen KA, Mohamed AM, Ibrahim MA. Physicochemical properties of for new genotypes of guar seeds (*Cyamopsis Tetragonoloba* L.). Am J Food Sci & Health. 2015;1:76-81.
23. Ezekiel TW, Timothy N, Tugga UA. Chemical Composition and Nutritional Value of *Cassia occidentalis* Seeds. International Journal of Biochemistry Research & Review. 2019;27(3):1-8.

24. Farah N, Srivastav S, Singh P, Mishra G. Phytopharmacological Review of *Cassia tora* Linn. (Fabaceae). Pelagia Research Library. Asian Journal of Plant Science and Research. 2011;1(1):67-76.
25. Garnayak DK, Pradhan RC, Naik SN, Bhatnagar N. Moisture-dependent physical properties of jatropha seed (*Jatropha curcas* L.). Industrial Crops and Products. 2008;27(2008):123-129.
26. Gharib-Zahedi, Taghi SM, Mousavi, Mohammad S, Moayedi, Ali, Garavand, *et al*. Moisture-dependent engineering properties of black cumin (*Nigella sativa* L.) seed. Agricultural Engineering International: The CIGR Ejournal, Manuscript. 1437, c2010, 12.
27. Gupta RK, Das SK. Physical properties of sunflower seeds. Agricultural Engineering Research. 1996;66(1997):1- 8.
28. Hrnčič, Knez, Maša, Ivanovski, Maja, Cör, *et al*. Chia Seeds (*Salvia hispanica* L.): An Overview - Phytochemical Profile, Isolation Methods, and Application Molecules. 2019;25(11):1-19.
29. Ixtaina, Vanesa Y, Nolasco, Susana M, Mabel TC. Physical properties of chia (*Salvia hispanica* L.) seeds. Industrial Crops and Products. 2008;28(2008):286–293.
30. Jackson ML. Soil chemical analysis Pub. Prentice Hall of Indian Pvt. Ltd. New Delhi; c1973.
31. Jain S, Patil UK. Phytochemical and pharmacological profile of *Cassia tora* Linn. - An Overview. Indian Journal of Natural Products and Resources. 2010;1(4):430-437.
32. Kabas, Onder, Yilmaz, Erdem, Ozmerzi, Aziz and Akinci, Ibrahim. Some physical and nutritional properties of cowpea seed (*Vigna sinensis* L.) Journal of Food Engineering. 2007;79(2007):1405–1409.
33. Kamble KJ, Deshmukh VM. Study of Engineering and Chemical Properties of Tarwad (*Cassia tora* L.) Seed Powder. International Journal of Agriculture Sciences, ISSN, 0975-3710; c2020.
34. Kenghe, Narayan R, Nimkar, Manohar P, Shirkole, Shankarrao S. Moisture dependent physical properties of lathyrus. Journal Food Sciences Technology. 2013;50(5):856–867.
35. Kingsly ARP, Singh DB, Manikantan MR, Jain RK. Moisture dependent physical properties of dried pomegranate seeds (*Anardana*). Journal of Food Engineering. 2006;75(2006):492–496.
36. Meena AK, Niranjan US, Yadav AK, Singh B, Nagariya AK, MRao M. Cassia tora Linn: A review on its ethnobotany, phytochemical and pharmacological profile. Journal of Pharmcy Research. 2010;3(3):557-560.
37. Milani E, Seyed M, Razavi A, Koocheki A, Nikzadeh V, Vahedi N, *et al*. Moisture dependent physical properties of cucurbit seeds. International Agrophysics. 2007;21:157-168.
38. Mohsenin NN. Physical properties of plant & animal materials. New York: Gordon Breach Science Publishers; c1970.
39. Olapade AA, Ajayi OA, Ajayi IA. Physical and chemical properties of *Cassia sieberiana* seeds. International Food Research Journal. 2014;21(2):767-772.
40. Paul V, Ramesh KV, Pandey R. Analysis of mineral nutrients: Sampling techniques and methods of digestion for plant samples. Manual of ICAR Sponsored Training Programme for Technical Staff of ICAR Institutes on Physiological Techniques to Analyze the Impact of Climate Change on Crop Plants; c2017. p. 77.
41. Pawar HA, D'mello PM. *Cassia tora* Linn.: An overview. International Journal of Pharmaceutical Sciences and Research. 2011;2(9):2286.
42. Pawar HA, Lalitha KG. Extraction, characterization, and molecular weight determination of *Senna tora* (L.) seed polysaccharide. Hindawi Publishing Corporation International Journal of Biomaterials; c2015.
43. Peng Fei, Fang, Fang, Xiang, Rui and Liu, Dan. Engineering properties of *Cassia tora* L. seeds and meal as a function of moisture content. Scientific Reports. 2022;12(2022):8651.
44. Pradhan RC, Naik SN, Bhatnagar N, Swain SK. Moisture-dependent physical properties of Karanja (*Pongamia pinnata*) kernel. Industrial crops and products. 2008;28(2008):155–161.
45. Razavi SM, Mortazavi SA, Matia-Merino L, Hosseini-Parvar SH, Motamedzadegan A, Khanipour E. Optimisation study of gum extraction from Basil seeds (*Ocimum basilicum* L.). International Journal of Food Science and Technology. 2009;44(9):1755-1762.
46. Sacilik K, Oozturk R, Keskin R. Some physical properties of hemp seed. Biosystems Engineering. 2003;86(2):191-198.
47. Shaikh, Rahimullah, Zainuddin Syed, Imran. Phytochemical, proximate and nutrient analysis of *Cassia Tora* seeds. International Journal of Pharmaceutical Science Invention. 2016;5(6):04-06.
48. Siddhuraja P, Vijayakumari K, Janardhanan K. Nutritional and antinutritional properties of the underexploited legumes *Cassia laevigata* willd. and *Tamarindus indica* L., Journal of Food Composition and Analysis. 1995;8(4):351–362.
49. Singh S, Singh SK, Yadav A. A review on Cassia species: Pharmacological, traditional and medicinal aspects in various countries. American Journal of Phytomedicine and Clinical Therapeutics. 2013;1(3):291-312.
50. Sologubik CA, Campa Nonec LA, Pagano AM, Gely MC. Effect of moisture content on some physical properties of barley. Industrial Crops and Products. 2013;43(2013):762-767.
51. Solomon WK, Zewdu AD. Moisture-dependent physical properties of Niger (*Guizotia abyssinica Cass*.) seed. Industrial crops and products. 2009;29:165–170.
52. Sonwani RK, Khokhar D, Patel S. Extraction of gum from charota (*Cassia Tora*) seeds and its characterization. Research Journal of Chemical and Environmental Sciences. 2018;6(4):39-44.
53. Tabatabaeefar A. Moisture-dependent physical properties of wheat. International Agrophysics. 2003;17:207–211.
54. Tavakoli H, Rajabipour A, Mohtasebi SS. Moisture-dependent some engineering properties of soybean grains. Agricultural Engineering International: the CIGR Ejournal. Vol. XI. 2009 Feb.
55. Tunde-Akintunde TY, Akintunde BO. Some physical properties of sesame seed. Biosystems Engineering. 2004;88(1):127-129.
56. Ukhun ME, Ifebigh EO. Compositional chemistry of *Cassia alata* seeds. Food chemistry. 1988;30(3):205-210.
57. Vadivel V, Janardhanan K. Chemical composition of the

underutilized legume *Cassia hirsute* L. Plant Foods for Human Nutrition. 2000;55:369–381.
58. Vadivel V, Janardhanan K. Nutritional and anti-nutritional attributes of the under-utilized legume, *Cassia floribunda* Cav. Food Chemistry. 2001;73(2):209–215.
59. WHO. Quality Control Methods for Medicinal Plant Materials, World Health Organization, Geneva; c1989. p. 1-114.
60. Williams ET, Timothy N, Tugga UA. Chemical composition and nutritional value of *Cassia occidentalis* seeds. International Journal of Biochemistry Research and Review. 2019;27(3):1-8.
61. Wyk Ben-Erik van, Wink, Michael. Medicinal plants of the world. Published in South Africa by BRIZA Publication, CK 1990/011690/23, Revised edition; c2017. p. 7.
62. Zewdu AD, Solomon WK. Moisture-dependent physical properties of tef seed. Biosystems Engineering. 2007;96(1):57–63.