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Post-harvest Application and Physicochemical Properties of Jamun (*Syzygium cuminii* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. Author SM designed the study, wrote the protocol, and wrote the first draft of the manuscript. Author RGK managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

Jamun (*Syzygium cuminii L.*) is a subtropical fruit that comes under myrtaceae family originated from the Indian subcontinent. India is the second largest producer of jamun with an annual production of 2.1 million ton which contributes 15.4% of world production. Jamun is a highly perishable seasonal fruit (May–June). Hence, processing and preservation are essential to ensure the availability of its products throughout the year. Engineering and physicochemical properties of the fruit play a crucial role in the design and development of processing equipment, handling of food products and processing. The engineering properties of jamun fruit, including physical, mechanical,

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and frictional characteristics, were investigated in this study. Additionally, the physicochemical properties of jamun juice, such as pH, total soluble solids (TSS), acidity, total phenolic content, total anthocyanin content, antioxidant activity and vitamin C, were measured as per standard procedures. Jamun contains 80 percent pulp and nearly 20 percent seed. The physical properties of jamun fruit, including length, width, thickness, sphericity, bulk density, and porosity, were determined to be 22.22 mm, 21.93 mm, 20.99 mm, 0.947, 0.67g/cm^3, and 32.48%, respectively. The firmness of the fruit was measured as 1.09 N and co efficient of friction of the fruit for different materials such as stainless steel, plywood, cardboard and glass were determined to be 1.25, 1.28, 1.56, 1.98, respectively. The physiochemical properties like moisture, pH, TSS, acidity, specific gravity, total phenolic content, antioxidant activity, total anthocyanin content and vitamin c were found to be 85.33 % (wb), 3.12, 13.14%, 0.81, 0.9, 256.76 mg/100ml, 86%, 1281 mg/100ml and 16 mg/100ml, respectively. These properties highlight its significant potential as a functional food and raw material for various food processing applications.

Keywords: Postharvest application; Jamun fruit; Jamun juice; physicochemical properties.

1. INTRODUCTION

Jamun (*Syzygium cuminii*) is an underutilized fruit tree native to the Indian subcontinent. It belongs to the family of myrtaceae. Jambul, black palm, java palm, and Indian blackberry are the common names of jamun. The promising values of phytochemicals, minerals and vitamins give a great therapeutic value for jamun. It is also referred as “Fruit for the Future” (Madani et al., 2021). Jamun has proven pharmacological properties on the animal system, including hypoglycemic, anti-inflammatory, antimicrobial, antioxidant, antidiarrheal, analgesic, astringent, and gastroprotective effects. Studies on the use of jamun for diabetes have demonstrated positive results. (Jagetia, 2024; Kaur, 2024; Kumar et al., 2022).

India ranks second in jamun production, with an annual output of 13.5 million tonnes in 2013, contributing 15.4% to the world's total estimated production (Pharate et al., 2018). The top producer of jamun is Maharashtra, with Tamil Nadu, Gujarat, Assam, Uttar Pradesh, and other states following closely behind. The jamun tree is frequently grown on homesteads. Ram jamun is a common variety in north India. Other Jamun varieties such as Konkan bhadoli, madhura, Badama, Bhado, Narendra Jamun 6 Narendra, Goma Priyanka, CISH J-42 (Seedless type), CISH J-37 are some of the well-known varieties of jamun (Patil et al., 2011; Singh et al., 2019). From Tamil Nadu in the south to the Indo-Gangetic plains in the north, jamun is grown extensively throughout India's largest regions. Jamun can grow in the saline area also.

Anthocyanin is the bioactive compound that is rich in jamun (Tavares et al., 2016). Jamun is used as the raw material for the production of various value-added food products in many Asian countries like China, India etc due to its high nutritional values (Santhalakshmy et al., 2015). The processed food such as jam, jelly, chips, squash, wine, vinegar, beverages and pickles are made by utilizing the jamun fruit (Lago-Vanzela et al., 2011). Incorporating jamun fruit, juice, seed and powder, several value-added products were made. It provides a good source of nutrition for food security. (Rasheed et al., 2024).

Jamun is a rich nutritious fruit but it is a seasonal one. The fruits are available during the months of May to June which differ with the genotype. In order to make the availability of jamun through the year, processing and preservation are important (George et al., 2023). Understanding the raw material is very important for developing good processing techniques, methods and equipment. The physical characteristics of fruits are crucial for machinery design and food processing. They also play a key role in post-harvest handling, such as sorting, grading, packaging, storage, and transportation. (Athmaselvi et al., 2014). The biochemical properties are useful in the design and formulation of innovative food products (Sood et al., 2018).

The objective of the study is to examine the engineering properties of jamun fruit and the physicochemical properties of both the fruit and juice, with the aim of improving quality and enhancing post-harvest handling of jamun fruit.

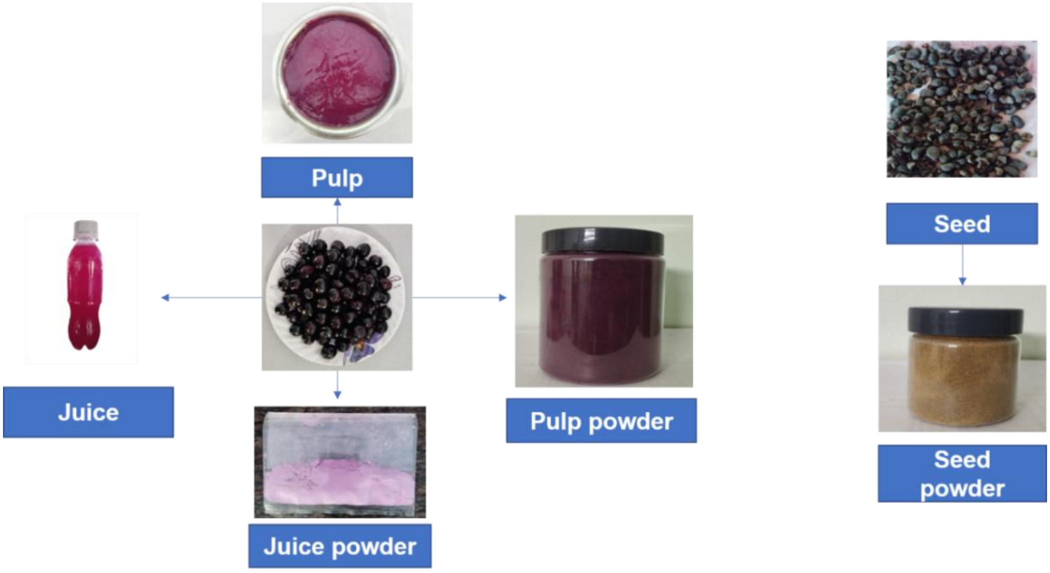

Fig. 1. Post-harvest processing of jamun fruit

2. MATERIALS AND METHODS

2.1 Sample Collection

Jamun fruits were procured from local market of Malappuram of Kerala. The following flow chart (Fig. 2) shows the preparation of jamun juice from jamun fruit.

2.2 Engineering Properties

Engineering properties are important in the area of design and development of equipment of post-harvest unit operations of agricultural processing (Sahay & Singh, 2020). Engineering properties of biological materials are classified into physical properties, mechanical properties, frictional properties, physiochemical properties and nutritional properties etc.

2.2.1 Physical properties

Physical properties of agriculture produce include shape, size, density, color, volume, surface area, porosity etc. were determined as per standard procedure.

2.2.1.1 Weight

Fruit weight was measured by an electronic balance with the accuracy 0.01 gram.

2.2.1.2 Axial dimensions

The axial dimensions are length, width and thickness. These dimensions of the fruits were measured by vernier caliper with least count of 0.02 mm.

2.2.1.3 Shape index (SI)

The shape index of the fruit was calculated by the following formula (Mohsenin, 1980):

$$SI = \frac{W+T}{2L} \quad \text{.................................} \ (1)$$

W- width (mm)
T- thickness (mm)
L- length (mm)

2.2.1.4 Geometric mean diameter (Dg)

Geometric mean diameter was calculated using the following formula mentioned by (Shousha et al., 2024):

$$Dg = (L * W * T)^{\frac{1}{3}} \quad \text{...........................} \ (2)$$

L - largest intercept
W - largest intercept perpendicular to l
T - largest intercept perpendicular each other

2.2.1.5 Arithmetic mean diameter (AMD)

The formula for calculation of AMD is as follows (Sasikumar et al., 2024):

$$Da = \frac{(L*W*T)}{3} \quad \text{..................................} \ (3)$$

2.2.1.6 Aspect ratio (AR)

The formula for calculation of AR is as follows (Dash et al., 2008):

$$AR = (\frac{W}{L})x100 \quad \text{...........................} \ (4)$$

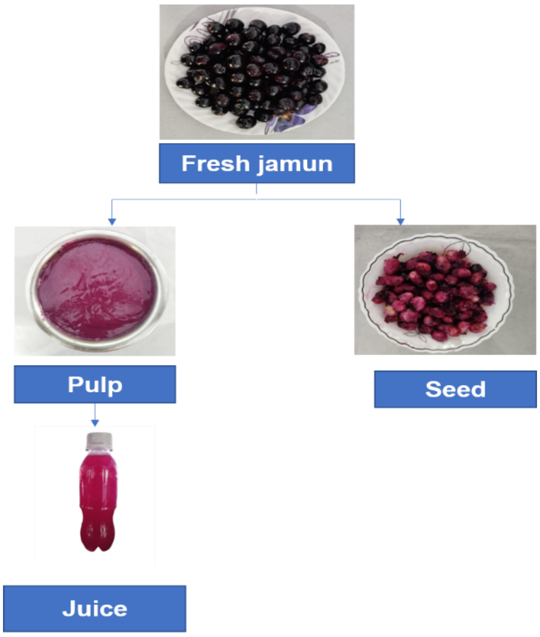

Fig. 2. Processing of jamun juice

2.2.1.7 Elongation ratio

The formula for elongation ratio is as follows:

$$ER = \frac{T}{W} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(5)}$$

2.2.1.8 Sphericity

Sphericity is normally used to express the shape and size of the material. It is calculated using the following formula (Shousha et al., 2024):

$$\text{Ø} = \frac{(L*W*T)^{\frac{1}{3}}}{L} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(6)}$$

2.2.1.9 Surface area

The fruit surface area was measured by the following formula (Sasikumar et al., 2024);

$$S = \pi * Dg^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(7)}$$

2.2.1.10 Fruit volume

Platform scale method was used for measuring the volume (Sahay & Singh, 2020):

2.2.1.11 Density

Density of any material can be expressed as ratio of weight of the material to volume of the material.

2.2.1.11.1 Bulk density

A 100 ml cylindrical glass container was filled entirely with jamun fruits in order to calculate the bulk density. Without crushing the fruits, the surplus jamun fruits were removed by repeatedly tapping the container. Using an electronic balance, weight was measured. The formula for bulk density follows (Işikli & Yilmaz, 2014).

$$\text{Bulk density (g/}cm^3\text{)} = \frac{Bulk\ mass\ (g)}{Total\ volume\ (cm^3)} \ldots \text{(8)}$$

2.2.1.11.2 True density

True density was determined using the toluene (C7H8) displacement method (Mohsenin, 1980; Shousha et al., 2024). The formula for true density is

$$\text{True density (g/}cm^3\text{)} = \frac{Mass\ of\ the\ individulal\ fruit\ (g)}{Volume\ of\ individual\ fruit\ (cm^3)} \ldots. \text{(9)}$$

2.2.1.11.3 Density ratio

Using the bulk density and true density measurements, the fruits' density ratio was determined (Işikli & Yilmaz, 2014).

$$D_r(\%) = \left(\frac{\rho_t}{\rho_b}\right) x100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(10)}$$

ρ_t = true density
ρ_b = bulk density

2.2.1.12 Porosity

Porosity was calculated using the values of bulk density and true density. The formula for porosity is given by (Bakane et al., 2016):

$$€ = \left(\frac{\rho t-\rho b}{\rho_t}\right) \times 100 \quad \text{……………………..… (11)}$$

2.2.1.13 Colour

The color was determined by colorimeter. It was expressed as L*, a*, b* value (*Sasikumar* et al., 2024)

2.2.1.14 Yield calculation

2.2.1.14.1 Pulp content

The term "pulp content" describes the fruit's edible component. After the seeds were removed from the fruits, it was measured using the formula below (Ghosh et al.,2016).

$$\text{Pulp content (\%)} = \frac{weight\ of\ the\ pulp\ (g)}{weight\ of\ the\ fruit\ (g)} \times 100 \ \ldots\ (12)$$

2.2.1.14.2 Juice content

The quantity of juice from fruit is expressed in terms of juice content. The juice of fruit was extracted using a fruit pulper and juice content was calculated as per the formula mentioned below (Zeng *et al.* 2019).

$$\text{Juice content (\%)} = \frac{weight\ of\ the\ juice\ (ml)}{weight\ of\ the\ fruit\ (g)} \times 10 \ \ldots\ (13)$$

2.2.1.14.3 Seed content

The inedible portion of the fruit which was separated to make pulp was taken for the calculation (Babu et al., 2019).

$$\text{Seed content (\%)} = \frac{weight\ of\ the\ seed\ (g)}{weight\ of\ the\ fruit\ (g)} \times 100 \ldots\ (14)$$

2.2.2 Mechanical property

Using an electronic penetrometer, the firmness of the fruit was tested (Jantra et al., 2018). The meter's sharp edge was positioned on the fruit's surface. To create a rupture on the fruit's surface, it was gradually compressed. It was noted how much force was needed to cause a rupture.

2.2.3 Frictional property

The frictional properties are important for designing of conveyer and moving parts in processing machineries. The coefficient of friction of fruits were determined by the following formula (Ghosh et al*.,* 2016):

$$\text{Coefficient of friction } (\mu) = \frac{F}{W} \quad \text{………… (15)}$$

F – frictional force required
W – weight of the fruits

2.3 Physicochemical Properties

The chemical properties like moisture content, pH, TSS, titratable acidity and nutritional content were determined for pulp and juice.

2.3.1 Moisture content

Moisture content was determined using the method given by (AOAC, 2012). 10g of jamun pulp was taken in a petri dish. The initial weight was noted. It was then placed in a hot air oven at the temperature of 105°C for 3 hrs. Weight of the samples were checked at frequent interval till the constant weight was reached. The moisture content was calculated by the following formula:

$$\text{Moisture content (wet basis \%)} = \frac{wi-wf}{wi} \times 100 \ \ldots\ (16)$$

wi – initial moisture
wf – final moisture

2.3.2 pH

The pH of the fruit sample was determined using a digital pH meter (AOAC, 2000). One gram of fruit juice was diluted to 10ml with water respectively. The pH was analysed with buffer (pH 4.7). Triplicate was taken from each sample.

2.3.3 Acidity

Acidity was determined by titrating sample with 0.1 N alkali (NaOH). One ml of fruit juice diluted to 10 ml with water respectively and approximatively 0.1 ml of phenolphthalein was added. It was titrated against 0.1 N NaOH solution until the pink colour appears. Three replications per each sample were taken. Results were expressed in terms of acid as gram of citric acid per gram (AOAC, 2000).

$$\text{Acidity} = \frac{\text{ml of 0.1 N NaOH} \times 0.0064}{volume\ of\ the\ sample \times 100} \ldots \quad (17)$$

2.3.4 Total soluble solids

Total soluble solids were measured at 20°C with a hand refractometer and the results were expressed as °Brix (AOAC, 2005).

2.3.5 Specific gravity

Specific gravity refers to the density difference of the substance. The formula for specific gravity follows:

Specific gravity of juice = $\frac{\text{density of juice}}{\text{density of water}}$ …. (18)

2.3.6 Bioactive compounds

2.3.6.1 Total phenolic content

The concentration of total phenols in the extracted samples were determined by using Folin-Ciocalteu Reagent (FCR). To an aliquot of 0.2ml of sample extracts, 2.5 ml of 1:1 FCR reagent was added and left for 5 mins. To that 2ml of unsaturated sodium carbonate solution (7.5% w/v) was added and incubated for 2 hrs at room temperature. Using a spectrophotometer, the absorbance was measured at 760 nm. The amount of total phenolics was determined and reported as mg GAE/100g FW. Calibration curve was made by using gallic acid (Wang et al., 2011).

2.3.6.2 Total anthocyanin content

0.5 mL of extract was combined with 10 mL of two buffers: 0.025 M potassium chloride (pH 1.0) and 0.4 M sodium acetate (pH 4.5) and allowed to sit at room temperature for 15 minutes prior to taking absorbance measurements at wavelength of 520 and 700nm (Nguyen & Nguyen, 2018).

Total anthocyanin content (mg/100 mL) = $\frac{A \times MW \times DF \times 1000}{\varepsilon \times 1}$ … ………………………….(19)

where:

A = (A520nm − A700nm) pH 1.0 − (A520nm − A700nm) pH4.5
MW (molecular weight) = 449.2 g/mol for cyanidin-3-glucoside
DF = dilution factor established in D
l = 1 cm
ε = 26,900 molar extinction coefficients, in L/mol cm, for cyanidin-3-glucoside

2.3.6.3 Antioxidant Capacity (DPPH)

The antioxidant capacity was measured for juice. It was measured using 2,2-Diphenyl-1-picrylhydrazyl (DPPH) assay. 1 mL of the sample extract was mixed with 3 mL of 0.1 mM methanolic DPPH solution then it was vortexed and place at dark for 30 min at room temperature. The absorbance reading was 517 nm. UV-Visible spectrophotometer was used to measure the absorbance reading (Nguyen & Nguyen, 2018). Triplicate reading was taken for the determination. It was calculated as follows:

DPPH scavenging effect (%) = (1- $\frac{A}{A0}$) *100 … (20)

where
A0 - control solution absorbance
A - DPPH solution absorbance

2.3.6.4 Ascorbic acid

Ascorbic acid present in fresh fruits can be calculated either volumetric method or colorimetric method. Volumetric method was adopted to estimate vitamin C content present in jamun fruit juice. 200 ml of dye solution was prepared in distilled water using 42 mg of sodium bicarbonate and 52 mg of 2, 6, dichloro indophenols. The dye is reduced to a colourless leucobase by ascorbic acid. The titrating medium, 4% oxalic acid, aids in identifying the titration's end point by giving it a pale pink hue. In an acidic media, the dye has the colour of pink. Stock standard solution was prepared by dissolving 100 mg of ascorbic acid in 100 ml of 4% oxalic acid in a standard flask (concentration 1 mg/ml). The working standard solution was obtained by diluting 10 ml stock solution to 100 ml with 4% oxalic acid (concentration 100 µg/ml) (Joy et al., 2015). Sample was prepared by 4% oxalic acid and titrated against the dye.

Ascorbic acid mg/100g = $\frac{0.5}{V1} \times \frac{V2}{5} \times \frac{100}{Vs} \times 100$ …. (21)

V1- titration value of blank
V2 – titration value of sample
Vs – weight of the sample

3. RESULTS AND DISCUSSION

The physicochemical characteristics of a fruit dictate its intended use, including its suitability for direct consumption, technological compatibility and processing potential all of which influence the quality of the final product (Najman et al., 2023). The weight of the fruit was in the range of 2.03g to 15.36g. The weight values indicated that Jamun had an uneven distribution of weight. According to the findings, the fruit's length was greater than its width and thickness. The measurements for the minimum and maximum length, width and thickness were 14.93 mm, 14.95 mm, and 14.12 mm, and 29.11 mm, 28.94

mm, and 28.72 mm, respectively. Varietal changes, species, rootstock utilised, edapho-climatic growing circumstances, and agro-inputs provided to the fruit-bearing trees may all contribute to variations in the physical characteristics of jamun fruit. Fruit weight and colour have an impact on the fruit's market value. The fruit's dimensions were used to determine its maturity (Panday et al., 2021). The geometric mean diameter of the fruit ranges from 14.27 mm at the minimum to 27.93 mm at the maximum. One of the fruit's key physical characteristics is its sphericity, which was measured to range from a minimum of 0.863 to a maximum of 1.0. The surface area was measured using the formula mentioned in the materials and methods section (section 2.2.1.9), with the lowest value being 639.6 mm^2 and the largest area measuring 2455.7 mm^2. The fruit's volume was measured using the platform scale method, which is used to calculate the volume of irregularly shaped materials. It was found that the lowest and greatest volumes of jamun fruits were 2.03 mm^3 and 15.06 mm^3, respectively.

Bulk density was determined by weighing and measuring the volume, with the lowest and highest values being 0.56 g/cm^3 and 0.69 g/cm^3, respectively. Porosity was measured using the formula mentioned in section 2.2.1.12, with the lowest and highest values being 30.31 and 33.52, respectively. The pulp percentage of the fruit ranged from 74.56% to 82.62%, while the seed percentage varied between 12.78% and 19.05%. The highest juice yield recorded was 50%. Firmness, a mechanical property, was measured using a penetrometer, with a recorded value of 1.09 N. The coefficient of friction was assessed for various materials, including glass, cardboard, stainless steel, and wood, with glass showing the highest value of 1.98. The fruit's moisture content was determined as wet basis, following standard procedures. The physicochemical properties and bioactive components of jamun juice, such as pH, total soluble solids (TSS), acidity, specific gravity, total phenolic content (TPC), total anthocyanin content (TAC), antioxidant activity (DPPH), vitamin C, and colour, were analysed according to standard protocols. The pH ranged from 3.12 to 3.29, TSS from 10 to 13, and acidity from 0.81 to 1.71. Akhila and Umadevi (2018) and Lavanya et al. (2018) were mentioned the similar findings. Table 4. revealed that jamun juice was high in anthocyanin and other bioactive compounds.

Consumer preferences for fruits and vegetables with consistent sizes and shapes are strongly influenced by dimensions, weight, and volume, thus these characteristics must be considered when designing effective grading systems (Afshari et al., 2023). From the Table 1 jamun weight and axial dimensions like length, width and thickness were found to be 6.679 g and 22.22, 21.93 and 20.99, respectively. The fruit with dark pulp and an oblong shape was also reported in Kshirsagar et al. (2019). The findings were similar to (Suradkar et al., 2017; Ghosh et al., 2017; Shahnawaz and Sheikh, 2011). From the results of different studies, the weight and axial dimensions are varied according to genotypes. These measures offer important information about the fruit's physical attributes, which helps with the classification and comprehension of its applicability for different botanical or culinary uses. Additionally, this will provide inspiration for postharvest machinery design. For scholars and learners researching its morphology and possible uses, it also provides accurate data. The geometric and arithmetic mean diameters were also computed (Table 1). The surface area affects how gases, such as carbon dioxide and oxygen, are exchanged between the fruit and its surroundings, which is crucial for ripening and preserving freshness (Sasikumar et al., 2024).

Yield calculations of jamun fruit such as pulp content, seed content and juice content values are more are less similar to the findings of (Singh and Swamy, 2021; Gosh et al., 2017; Babu et al.,2019). Ningot et al. (2017) reported the pulp content of 53 to 87 %, respectively. The total phenolic content and antioxidant values were 256.76 mg/100 ml and 86%, respectively, whereas the anthocyanin content in jamun juice was 1824 mg/100 ml. Anthocyanin is the main compound for the fruit colour. Ascorbic acid content was in the range of 16 to 18 mg/100ml, respectively. The colour values of juice such as L*, a* and b* values were measured as 17.43, 25.57 and 8.57, respectively. The positive values of the colour indicated that jamun juice having lightness value. The values of the results are similar with the previous studies. Suradkar et al. (2017) reported that jamun fruit contains ascorbic acid 21.48 mg/100 ml and antioxidant activity of 95.81%, respectively (Kaur and Qadri , 2024).

Table 1. Physical properties of jamun fruit

Properties	Values ±SD
Weight (g)	6.679±0.92
Axial dimensions L(mm) W(mm) T(mm)	 22.22±3.65 21.93±3.90 20.99±3.78
Shape index	0.96±0.05
Geometric mean diameter (mm)	21.04±3.55
Arithmetic mean diameter (mm)	21.72±3.70
Aspect ratio	0.98±0.06
Elongation ratio	0.95±0.04
Sphericity	0.947±0.03
Surface area (mm^2)	1427±487
Volume (mm^3)	7.28 ± 4.1
Bulk density (g/cm^3)	0.67±0.01
True density (g/cm^3)	1±0.002
Density ratio	1.48±0.04
Porosity (%)	32.48±1.41
Colour (Pulp) L* a* b*	 15.43±0.73 26.3±0.62 -5.3±0.32
Pulp content (%)	79.20±2.1
Juice content (%)	50.20±5.1
Seed content (%)	17.23±1.7

Table 2. Mechanical property of jamun fruit

Property	Values ±SD
Firmness (N)	1.09±0.56

Table 3. Frictional property of jamun fruit

Co efficient of friction (μ)	Values ±SD
Stainless steel	1.25
Plywood	1.28
Cardboard	1.56
Glass	1.98

Table 4. Physiochemical properties of jamun juice

Properties	Values ±SD
Moisture content of pulp (%)	85.33
pH	3.12±0.01
TSS (%)	13.14±0.2
Acidity	0.81±0.07
Specific gravity	0.9±0.0
Total phenolic content (mg/100ml)	256.76±0.52
Total anthocyanin content (mg/100 ml)	1284.14±1.66
Antioxidant activity (% DPPH)	86±0.04
Ascorbic acid (mg/100 ml)	16±1.25
Colour L* a* b*	 17.43±0.65 25.57±4.07 8.57±2.24

** Moisture content on wet basis*

4. CONCLUSION

The study of the engineering and physicochemical properties of jamun fruit provides essential insights for the design and development of efficient food processing machines well as innovative food products. Understanding these properties, such as sphericity, bulk density, porosity, firmness, moisture content and bioactive components, facilitates the optimization of handling, processing and storage techniques. This knowledge supports the production of high-quality jamun-based products while ensuring minimal waste and improved processing efficiency. Consequently, these findings serve as a foundation for advancing value-added product development and promoting the utilization of jamun in the food industry. These characteristics not only influence consumer preferences but also play a significant role in the processing, storage, and preservation of fruits. By optimizing factors such as ripening conditions and handling procedures, fruit quality can be improved, and post-harvest losses can be minimized.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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