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Research Article

Utilization of Jamun Fruit (*Syzygium cumini* L.) for Value Added Food Products

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The goal of this study is to draw attention to the vital nutrients, health advantages, and potential for encouraging the consumption of jamun fruits (*Syzygium cumini* L.) and making the most of their useful features to create valuable goods. In the current study, efforts have been made to evaluate the jamun fruit's physicochemical characteristics and bioactive components. Moreover, ready-to-serve beverages, squash, syrup, and jam, have been prepared, and their quality has been monitored throughout the storage. Jamun fruit had an ovoid or spherical form and was a dark purple tint. The initial analysis of fruits showed 83.59% moisture, 17.56 °Brix, 3.63 pH, 328.50 mg cyd-3-Glu/100 g anthocyanin, 219.21 mg GAE/100 g total phenolics, 91.33 mg QE/100 g total flavonoids, and 91.33% antioxidant activity. High-performance liquid chromatography examination, revealed the existence of three main anthocyanin pigments, delphinidin 3, 5-diglucoside, petunidin 3, 5-diglucoside, and malvidin 3, 5-diglucoside, which were measured at 175.80, 156.50, and 83.12 mg/100 g, respectively. While the main phenolic compounds present were chlorogenic, gallic, caffeic, vanillic, and catechin, with respective concentrations of 14.22, 12.18, 10.33, 6.44, and 4.13 mg/100 g. Total soluble solids, pH, and total sugars increased with the storage of jamun products, but acidity, total phenolic, and anthocyanin contents declined. In conclusion, jamun is a fruit that has promise for the future of producing useful goods. The various jamun fruit-based products met good standards and were sensory-acceptable.

1. Introduction

Jamun (*Syzygium cumini* L.) is a tropical fruit with purple peel. It is a member of the Myrtaceae family. Jamun fruits are also known as pompozia in Egypt, jambul, java plum, Indian blackberry, and black plum in various parts of the world [1]. Jamun is a petite and delicate fruit. It is one of the underutilized crops because there is no organized farming [2]. It is an extremely perishable fruit having a very short shelf life of 1-2 days under ambient conditions [3]. Ancient medicine made extensive use of jamun fruits to treat a wide range of illnesses and physiological disorders [4]. It is used to treat conditions such as spleen illnesses, viral infections, gastric ulcers, allergies, cancer, headaches, sore throats, and diarrhea [5–7]. This fruit is supposed to help with diabetes and blood purification. The presence of a significant amount of iron in the jamun fruits facilitates an increase in hemoglobin count and acts as a blood purifying agent [8, 9]. This fruit or its juice can be consumed by diabetics without raising blood sugar levels [8, 10–12].

Jamun fruits are a good source of minerals, vitamins, and phytochemicals compounds (phenolic, flavonoids, gallic acid, anthocyanins, and tannins) which have powerful antioxidant capabilities [13–15]. Phenolic compounds found in jamun include chlorogenic acid, epicatechin, protocatechuic acid, vanillin, syringic acid, ellagic acid, gallic acid, caffeic acid, pyrogallol, ferulic acid, catechin, and vanillic acid [2, 16]. Jamun fruits are a good source of the monosaccharides glucose, fructose, and mannose, as well as the disaccharides sucrose, maltose, galactose [17], amino acids asparagine, glutamine, alanine, cysteine, and tyrosine, as well as the fat-insoluble vitamins, ascorbic acid, thiamine, and niacin [18].

Yet, this fruit does not find a place on the table due to its astringent flavor and the purple stain it leaves on the tongue [19]. Although having excellent nutritional and therapeutic qualities, they are not widely cultivated. In addition, this fruit is scarce because it is seasonal and perishable. The fruit's delicate and juicy texture also contributes to its substantial postharvest losses. Hence, adding value through processing will be the only practical method for making use of the fruit economically. Therefore, jamun fruits should be used to create value-added food products because of their bioactive ingredients and nutritional value.

Fruit can be made into a variety of food products, such as jam, jelly, and squash. This is the greatest way to commercialize the jamun fruit. A new export market might be opened up by turning jamun fruits into a variety of exotically flavored products with higher nutritional and sensory properties. Jamun pulp, dried jamun, fermented jamun products, or seed powder have all been used to create a variety of products [20–23].

Based on the aforementioned ideas, this experiment was carried out with the following goals:

To assess the bioactive components of jamun fruits, such as their phenolic, flavonoid, and anthocyanin profiles.

To evaluate the physical and chemical properties of jamun fruits.

To develop ready-to-serve beverages, squash, syrup, and jam, that are based on jamun fruits.

To assess the organoleptic properties of prepared beverages, squash, syrup, and jam.

2. Materials and Methods

2.1. Materials

2.1.1. Fresh Jamun Fruits. The jamun fruits (pomposia) were purchased from a nearby farm in Edfina, El-Behera Governorate, Egypt, and delivered straight to the lab in an ice box.

2.1.2. Produced Jamun Products. Various value-added jamun products (beverages, squash, syrup, and jam) were used.

2.1.3. Chemicals and Reagents. All of the materials and standards utilized in this investigation, such as gallic acid, malvidin 3-O-glucoside, pelargonidin 3-O-glucoside, delphinidin 3-glucoside, cyanidin chloride, malvadin chloride, pelargonidin chloride, and rutin (Sigma-Aldrich, UK), were either of analytical grade or high-performance liquid chromatography (HPLC) grade with purity levels above 98%.

2.2. Experimental Procedure. To remove any dust or foreign substances from the surface of fresh fruits, water with 3% $CaCl_2$ was used to wash the fruits [24]. The seeds were removed, and the pulp was pressed and homogenized for around five min at a high speed using a blender (Bajaj Mixer, Rex 500-Watt Mixer Grinder, Telangana, India). Fruit juice was filtered through nylon fabric after extraction. The juice was then preserved for later processing and preparation as a beverage, a squash, and syrup [25, 26].

For beverages, squash, syrup, and jam, sugar was added to boost total soluble solids (TSSs) to 14, 45, 56, and 68°Brix, respectively, and the sodium benzoate was added at 200 ppm. The beverage was heated to 85°C in boiling water for 20 min, poured into sterilized 200 mL bottles, and sealed with crown corks. The jam was packaged in 200 mL sterilized broad-mouth glass bottles, while the syrup and squash were packaged in 750 mL long glass bottles. All of the products were kept at room temperature for 6 months.

2.3. Analysis Methods

2.3.1. Physical Properties. Visual observations of physical attributes including color and shape were made. A digital vernier caliper was used to measure the length (in cm) and a sensitive balance to calculate the average fruit weight (in g), and weigh the edible part, seed, and juice percentages.

2.3.2. Chemical Properties. Using a hand refractometer, the TSS was estimated following the recommended procedure [27]. The pH was determined using a digital pH meter (Jenway, UK). The titration method was used to calculate the titratable acidity (%, as citric acid) [28]. The volumetric approach was used to estimate the amount of total and reducing sugars [29]. The ascorbic acid level was determined using a 2–6,dichlorophenol-indophenol visual titration method [30].

(1) Total Anthocyanin. The pH-differential approach was used to measure the total amount of anthocyanins [31]. Briefly, 1.0 mL of fruit pulp extract was mixed with 9 mL of buffers with pH values of 1.0 (KCl-HCl) and 4.5 (NaOAc-CH_3COOH), and the mixture was then allowed to sit at a room temperature for 20 min in the dark. Absorbance was measured at 700 nm. Total anthocyanins were expressed as cyanidin 3-glucoside equivalents mg/100 g of pulp weight.

(2) HPLC Identifications. The HPLC (Agilent, model-LC 1100 series) was used to separate and identify anthocyanins [32, 33]. Using cyanidin 3-O-glucoside as a reference, the anthocyanins were quantitatively assessed.

(3) Proximate Analysis. According to AOAC [34], proximate analysis of the contents of moisture, proteins, lipids, fiber, and ash was performed. In the meantime, the formula was used to calculate carbohydrates using the different approach.

$$\text{Carbohydrates (\%)} = 100 - (\text{water} + \text{protein} + \text{fat} + \text{ash}). \tag{1}$$

(4) Phytochemical Evaluation. Phytochemicals extraction was done according to the method of Alshallash et al. [35] with slight modifications.

(5) Total Phenolic Content (TPC). The Folin–Ciocalteu reagent was used to determine the TPC. Gallic acid equivalents (GAEs) were used to measure the results and were given as mg/100 g [36].

(6) Total Flavonoids Content (TFC). TFC was determined using the colorimetric method with aluminium chloride, and the concentration was represented in terms of mg of quercetin/100 g [37].

(7) DPPH Radical Scavenging Assay. The measurement of the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging activity was evaluated according to the method described by Alshallash et al. [35].

(8) Identification of Phenolic and Flavonoid Compounds. Using HPLC (Hewlett Packard, series 1050, USA) at 280 and 330 nm for the phenolic and flavonoid components, respectively, the phenolic and flavonoid constituents of the jamun fruit pulp extracts were identified as described by Mattila et al. [38]. The temperature of the column (C18 column 1504.5 mm) was kept at 35°C. Methanol and acetonitrile were used as the mobile phases for the gradient separation, and a flow rate of 1 mL/min was used. Standards for phenolic and flavonoid compounds were dissolved in a mobile phase and added to an HPLC column. Using a standard graph in triplicate, the amounts of phenolic and flavonoid components were determined.

(9) Mineral Content. The sample was ashed at 550°C in an electric furnace to determine the mineral components. Atomic absorption spectroscopy was used to determine the mineral composition of the ash after it had been dissolved in 6 N HCl (AAS, AA4000, Spectrum-SP, Darmstadt, Germany). Mg, Na, Ca, K, Fe, Zn, and Cu concentrations were measured with the aid of a flame photometer (128, Systronics, Ahmedabad, India). The content of P was determined using a UV-VIS spectrophotometer [27, 39]. The mineral values were calculated as mg/100 g samples.

2.3.3. Sensory Evaluation. A panel of experts performed an organoleptic evaluation of the ready-to-serve beverages, squash, syrup, and jam to evaluate the appearance, taste, color, flavor, texture, and overall acceptability. They ranked the foods on a scale of 1 to 9, with 9 being considered excellent, 5 being considered relatively good, and 1 is considered subpar.

2.4. Statistical Analysis. For data analysis in the current study, the SPSS software (22) was applied. For each sample, each of the selected assays was run in triplicate. Finding significant differences between the gathered data with a 0.05 level of confidence was done using the analysis of variance (ANOVA) test.

3. Results and Discussion

3.1. Quality Attributes of Fresh Jamun Fruits

3.1.1. Physical Properties. Table 1 summarizes the jamun fruit's physical characteristics. The fruits were ovoid or spherical and blackish purple in color. Pandey et al. [40] recorded similar observations in the indigenous jamun fruit cultivar.

The average fruit weight, length, diameter, pulp (%), seed (%), and juice (%) were recorded at 5.36 g, 2.68 cm, 1.82 cm, 72.57%, 27.43%, and 33.24%, respectively. Akhila and Hiremath [41] observed similar results and that the fruit's weight, length, and width were 9.1 g, 2.73 cm, and 2.28 cm, respectively. In this respect, Sardar et al. [13] reported that the average values for jamun fruit's weight, length, diameter, pulp yield, and seed yield were 9.08 g, 2.9 cm, 2 cm, 72.17%, and 27.83%, respectively. Pandey et al. [40] reported the average pulp, seed, and juice % as 69.63, 30.37, and 21.67%, respectively of the jamun fruit. These changes in the physical characteristics of jamun fruit may be caused by a number of variables, including the species, rootstock utilized, agro inputs employed on the plants bearing that fruits, the time of harvest, and edaphoclimatic conditions of growth.

3.1.2. Physiochemical Properties. The data for the physicochemical properties of jamun fruits are presented in Table 2. From Table 2, it could be observed that the pH, titratable

Table 1: Physical properties of fresh jamun fruits.

Properties	Result
Color	Blackish purple
Shape	Ovoid/round
Fruit average weight (g)	5.36 ± 0.21
Fruit length (cm)	2.68 ± 0.17
Average diameter (cm)	1.82 ± 0.04
Pulp (%)	72.57 ± 0.12
Seed (%)	27.43 ± 0.22
Juice (%)	33.24 ± 0.18
pH	3.63 ± 0.12
Titratable acidity (%) (as citric acid)	1.32 ± 0.06
TSS °(Brix)	17.56 ± 0.88

Mean ± standard deviation.

Table 2: Physicochemical properties of fresh jamun fruits.

Properties	Result
pH	3.63 ± 0.12
Titratable acidity (%) (as citric acid)	1.32 ± 0.06
TSS (Brix)	17.56 ± 0.88

Mean ± standard deviation.

Table 3: Chemical composition of fresh jamun fruits.

Compounds (%)	Value*
Moisture	83.59 ± 0.24
Crude protein	1.85 ± 0.15
Crude fat	0.48 ± 0.12
Crude fiber	1.03 ± 0.09
Total ash	2.58 ± 0.02
Total sugars	13.41 ± 0.11
Reducing sugars	9.56 ± 0.23
Nonreducing sugars	3.85 ± 0.19

*Mean ± standard deviation.

acidity, and TSS of jamun fruit pulp were 3.63, 1.32%, and 17.56°Brix, respectively. This indicated that jamun fruit followed the acidic foods. Similar findings were reported for pH (3.0–3.77), titratable acidity (0.8–5.25%), and TSS (8–19.36°Brix) of jamun fruits [3, 13, 41, 42].

The data given in Table 3 indicate that the % of moisture, crude protein, crude fat, total ash, crude fiber, total sugars, reducing sugars, and nonreducing sugars of jamun fruits were 83.59, 1.85, 0.48, 1.03, 2.58, 13.41, 9.56, and 3.85%, respectively. The results are in agreement with the findings of [13, 19, 40], which observed that the jamun fruit contained moisture, protein, fat, ash, and carbohydrates among the ranges of 80.75–86, 1.12–4.37, 0.149–1.6, 0.32–4.51, and 13.58–16.6%, respectively. Also, our results are following those reported by the authors in [3, 40, 41] which observed the jamun fruits contained 9.85–12.6% total sugar, 5.92–8.9% reducing sugar, and 2.56–6.96% nonreducing sugar. The nutrient composition of jamun fruit depends on the freshness, climate and season, and type of soil [19].

Results of the analysis of the jamun fruit's ascorbic acid, total anthocyanin, total phenolics, total flavonoids, and antioxidant activity content are shown in Table 4. It could be noticed that the jamun fruit contained high amounts of

Table 4: Bioactive compounds (%) of fresh jamun fruits.

Bioactive compounds (%)	Value*
Ascorbic acid (mg/100 g)	108.50 ± 0.233
Anthocyanins (mg cyd-3-Glu/100 g)	328.50 ± 0.16
Total phenolic content (mg/100 g GAE)	219.21 ± 0.33
Total flavonoids (mg QE/100 g)	86.77 ± 0.25
Antioxidant activity (%)	91.33 ± 0.24

*Mean ± standard deviation.

ascorbic acid (108.50 mg/100 g), total anthocyanin (328.50 mg cyd-3-Glu/100 g), TPC (219.21 mg GAE/100 g), TFC (86.77 mg QE/100 g), and antioxidant activity (91.33%) (Table 4). These findings demonstrate that jamun fruits are a good source of bioactive substances. In accordance with the findings similar to Suradkar et al. [19], Gomez et al. [3], and Rajan et al. [43] who found that ascorbic acid, anthocyanins, TPC, TFC, and antioxidant activity of jamun fruits were 21.48–27.9 mg/100 g, 147.88–349 mg/100 g, 182.42–2133.5 mg GAE/100 g, 78.06–3110 mg QE/100 g, and 95.81%, respectively. A number of antioxidant substances, including ascorbic acid, phenols, and anthocyanins, which are all found in high concentrations in the jamun fruit, may have contributed to the rise in DPPH %. Many factors, including soil fertility, cultivar, maturation stage, agricultural practices, location, climate, and other environmental factors might affect the bioactive composition of jamun fruits [40, 44].

The mineral content of jamun fruits is presented in Table 5. Jamun fruits had higher contents of K, P, Mg, Ca, Mn, and Fe which recorded 366.17, 213.72, 158.90, 59.24, 38.12, and 33.81 mg/100 g, respectively. In addition, jamun fruits have the lowest content of copper and zinc (4.79 and 6.32 mg/100 g, respectively). Similar results were obtained by Sardar et al. [13] who reported that calcium, magnesium, phosphorus, iron, potassium, zinc, sodium, and copper, were found to be 54.55, 166.7, 152.65, 33.2, 358.5, 1.215, 8.75, and 0.105 mg/100 g, respectively.

(1) Identification of Anthocyanins in Jamun Fruits by HPLC. The presence of cyanidin diglycosides in the jamun fruit is what gives it its purple hue [45]. Cyanidin, peonidin, delphinidin, petunidin, and malvidin are the common anthocyanidins present in jamun fruits [46, 47]. Jamun fruit's anthocyanin pigments were extracted, separated, and identified using HPLC (Table 6). There are three main anthocyanin components for jamun fruits, identified by HPLC separation as delphinidin 3, 5-diglucoside, petunidin 3, 5-diglucoside, and malvidin 3, 5-diglucoside which represented to be 175.80, 156.50, and 83.12 mg/100 g, respectively, while peonidin 3, 5-diglucoside, delphinidin 3-glucoside, and cyanidin 3, 5-diglucoside recorded 39.85, 29.32, and 18.91 mg/100 g, respectively.

Similar results were reported by Sharma et al. [48] who found that major anthocyanins of jamun include delphinidin 3, 5-diglucoside, petunidin 3, 5-diglucoside, and malvidin 3, 5-diglucoside, while cyanidin 3, 5-diglucoside and peonidin 3, 5-diglucoside. In this respect, Lestario et al. [44] reported that major anthocyanins include delphidin 3,

Table 5: Mineral content (mg/100 g) of jamun fruits.

Minerals	Value (mg/100 g)
Calcium	59.24
Potassium	366.17
Magnesium	158.90
Sodium	7.42
Phosphorus	213.72
Iron	33.81
Copper	4.79
Manganese	38.12
Zinc	6.32

Table 6: Identification of anthocyanins in the jamun fruit by HPLC.

Anthocyanin	Value (mg cyd-3-Glu/100 g)
Delphinidin 3,5-diglucoside	175.80
Cyanidin 3,5-diglucoside	18.91
Petunidin 3,5-diglucoside	156.50
Peonidin 3,5-diglucoside	39.85
Delphinidin 3-glucoside	29.32
Malvidin 3,5-diglucoside	83.12
Cyanidin 3-glucoside	9.17
Petunidin 3-glucoside	1.18
Malvidin 3-glucoside	0.36

5-diglucoside (responsible for 37–48% of the total anthocyanins), followed by petunidin (29–33%) and malvidin (19–27%), while cyanidin (3%) and peonidin (1-2%). The variety of raw materials, growing conditions, environment, and the extraction process, as well as identification, may all have an impact on the results [49]. Furthermore, five anthocyanins without acylating groups were identified as 3, 5-diglucoside derivatives of delphinidin (41.29%), petunidin (27.79%), malvidin (25.60%), cyanidin (4.19%), and peonidin (1.13%). These findings show that anthocyanin is abundant in jamun fruits, particularly ripe fruits.

Anthocyanins are responsible for the fruit's purple-to-black color and its great antioxidant capacity [50]. This explains why the jamun fruit's anthocyanin-rich extract has a high potential for antioxidants and can be employed as a nutraceutical component.

(2) Identification of Phenolic and Flavonoid Compounds in Jamun Fruits using HPLC. Phenolic compounds are the most significant bioactive components of fruits because they have the ability to neutralize or prevent the generation of free radicals. The results of measuring the concentration of each phenolic component from the corresponding calibration curve are shown in Table 7. In the jamun fruits, a total of 14 polyphenolic compounds were found. According to the results, the main phenolic constituents were chlorogenic acid, gallic acid, caffeic acid, vanillic acid, and catechin, which recorded 14.22, 12.18, 10.33, 6.44, and 4.13 mg/100 g, respectively. In contrast, the lowest concentrations were recorded for ellagic acid and cinnamic acid (0.89 and 0.07 mg/100 g, respectively). The results obtained coincided with those of Branco et al. [51] who reported that chlorogenic acid (20.5 mg/100 g) and gallic acid (2.8 mg/100 g) were the major phenolic compounds present in the fresh jamun pulp. The extract of jamun fruits contained high amounts of quercetin, hesperidin, naringin, and kaempferol compounds being 4.18, 2.70, 2.35, and 1.12 mg/100 g, respectively, and low amounts of rutin, rosmarinic acid, and apigenin (0.52, 0.23, and 0.06 mg/100 g), respectively. Abd El-Salama et al. [52] mentioned that hesperidin (2.70 mg/100 g) and naringin (2.35 mg/100 g) were the major flavonoid compounds in the jamun fruit flesh extract.

3.2. Effect of Storage on Properties of Jamun Fruit Products. Any food product's stability during storage is a crucial factor. To determine the storage stability of jamun fruit products (beverages, squash, syrup, and jam), at room temperature (25 ± 5°C), the concentration of different physicochemical properties, phytochemicals, and antioxidant activities was determined for 6 months of storage, taking measurements at the interval every month.

3.2.1. Changes in Physicochemical Attributes. Physicochemical changes in jamun products during storage are presented in Table 8.

(1) TSS. TSS of beverages, squash, syrup, and jam is a measure of the product's sweetness, which ultimately impacts the acceptability of the product by consumers. The initial TSS beverages, squash, syrup, and jam were 14.31, 45, 56, and 58.5 °Brix (Table 8). The TSS of the jamun fruit products gradually increased during storage, reaching 16.5, 48.1, 57, and 69 °Brix for beverage, squash, syrup, and jam, respectively. Upward trend in TSS of jamun products towards the end period of storage may be due to the formation of simple sugars such as glucose and fructose caused by inversion of sucrose [3].

(2) Titratable Acidity and pH. The acidity content in fruit products plays a significant role in the flavor of processed fruit products, which ultimately reflects consumer preferences. The preference decreases with increasing acidity, although higher acidity helps preserve food samples' quality for longer [3]. The acidity content of beverages, squash, syrup, and jam was 0.3, 0.29, 0.33, and 0.85%, respectively (Table 8). With increasing storage time, all products generally showed a minor reduction in titratable acidity. The fall in acidity during storage may be caused by the chemical interactions of organic acids with carbohydrates and amino acids [42, 53]. On the contrary, the initial pH of beverages, squash, syrup, and jam was 3.15, 3.24, 3.25, and 3.9, respectively.

With storage, nonsignificant increases in the pH values were observed, reaching 3.95, 3.26, 3.69, and 3.19, respectively. The acid degrading may be the cause of the pH noticeable rise with storage. Our findings are consistent with the results of Khayum et al. [54] and Bhatt et al. [55], which revealed that the acidity of jamun products gradually decreased with storage in accordance with rises in pH values.

Table 7: Identified phenolic and flavonoid compounds (mg/100 g) of the jamun fruit.

Phenolic	Value (mg/100 g)	Flavonoids	Value (mg/100 g)
Caffeic acid	10.33	Rutin	0.52
Gallic acid	12.18	Naringin	2.36
Ferulic acid	4.09	Quercetin	4.18
Chlorogenic acid	14.22	Kaempferol	1.13
Pyrogallol	3.15	Hesperidin	2.70
p-Coumaric acid	1.52	Apigenin	0.09
Catechin	4.13	Rosmarinic acid	0.23
Vanillic acid	6.44	7-Hydroxy-flavone	0.05
4-Hydroxybenzoic acid	1.06		
Epicatechin	1.21		
Ellagic acid	0.89		
Cinnamic acid	0.07		
Protocatechuic acid	1.78		

Table 8: Physicochemical changes of jamun fruit products throughout six months of storage at room temperature.

Characteristics	Beverage			Squash			Syrup			Jam		
	Storage period (month)											
	0	3	6	0	3	6	0	3	6	0	3	6
TSS (°Brix)	14.31 ±0.21	15.30 ±0.14	16.50 ±0.10	45.00 ±0.07	46.40 ±0.18	48.10 ±0.09	56.00 ±0.03	56.80 ±0.22	57.00 ±0.09	68.50 ±0.13	68.9 ±0.11	69.0 ±0.07
Acidity (%)	0.30 ±0.06	0.28 ±0.05	0.27 ±0.11	0.29 ±0.03	0.28 ±0.19	0.25 ±0.03	0.33 ±0.11	0.32 ±0.18	0.31 ±0.01	0.85 ±0.15	0.84 ±0.05	0.81 ±0.02
pH	3.90 ±0.02	3.93 ±0.08	3.95 ±0.12	3.24 ±0.14	3.25 ±0.22	3.26 ±0.18	3.25 ±0.14	3.68 ±0.21	3.69 ±0.17	3.15 ±0.12	3.17 ±0.10	3.19 ±0.11
Total sugars (%)	10.50 ±0.12	11.40 ±0.24	12.60 ±0.22	37.40 ±0.16	38.0 ±0.22	39.00 ±0.21	60.40 ±0.32	62.2 ±0.08	63.30 ±0.18	54.20 ±0.12	56.20 ±0.18	57.40 ±0.16
Reducing sugars (%)	9.80	10.50 ±0.33	16.60 ±0.34	18.30 ±0.31	19.50 ±0.25	23.80 ±0.24	39.60 ±0.30	42.80 ±0.13	46.8 ±0.18	30.10 ±0.20	33.50 ±0.16	36.6 ±0.13
Anthocyanins (mg/100 g)	96.50 ±0.13	93.40 ±0.18	81.60 ±0.23	120.30 ±0.17	118.00 ±0.33	115.30 ±0.30	128.80 ±0.28	125.30 ±0.19	120.80 ±0.20	184.33 ±0.26	175.40 ±0.13	169.20 ±0.32
Total phenolic content (mg/100 g)	351.10 ±0.0.14	332.22 ±0.19	301.05 ±0.16	222.14 ±0.27	200.00 ±0.37	192.31 ±0.27	172.18 ±0.31	141.30 ±0.22	136.12 ±0.18	153.11 ±0.22	145.00 ±0.16	136.15 ±0.28
Antioxidant activity (%)	63.44 ±0.08	60.88 ±0.22	55.45 ±0.14	53.22 ±0.20	52.67 ±0.19	50.33 ±0.18	51.65 ±0.19	49.46 ±0.23	45.22 ±0.21	48.55 ±0.19	47.32 ±0.22	43.67 ±0.25

Results are expressed as means ± standard deviation.

(3) Total Sugars and Reducing Sugar. All jamun fruit products maintained at room temperature showed a noticeable increase in total sugars and reducing sugar (%) until the end of the experiment (Table 8). The hydrolysis of polysaccharides into simple compounds may be the possible reason [54, 56]. The increases in total and reduced sugar throughout storage may be attributable to the breakdown of starch into sugars. The rise in sugars perhaps results from faster reactions brought on by high ambient temperatures. According to Khayum et al. [54] and Bhatt et al. [55], jamun syrup has been showing a similar pattern of rising total sugar levels.

(4) Anthocyanin. Anthocyanin is responsible for the products appealing hue [57]. Among phytochemicals, anthocyanins are recognised to be the most vulnerable to deterioration during storage [2]. Decrease in the level of anthocyanins in the jamun products with storage could be due to the combined action of presence of light, temperature, pH level, and presence of enzymes and availability of oxygen [3]. Throughout storage, beverage, squash, syrup, and jam all significantly lost anthocyanin ($P < 0.05$). For beverages, squash, syrup, and jam, respectively, the total anthocyanin concentration was 96.5, 120.3, 128.8, and 169.2 mg/100 g at zero time. After six months of storage, these values were 169.20, 120.80, 115.30, and 81.60 mg/100 g (Table 7). This could be a result of the unstable anthocyanins produced when protective 3-glucoside linkages hydrolyze [58]. The increases in anthocyanin breakdown may be related to the nonenzymatic Maillard reaction and thermal degradation that take place when reducing sugars are present during processing or storage. The Maillard reaction's by-products readily combine with anthocyanins to generate molecules that are brown in hue. At the end of the storage time, the polymeric color increases, which is related to the anthocyanin deterioration [2, 59].

Several researchers discovered a significant decline in anthocyanins in diverse products with storage [2, 54, 55, 60].

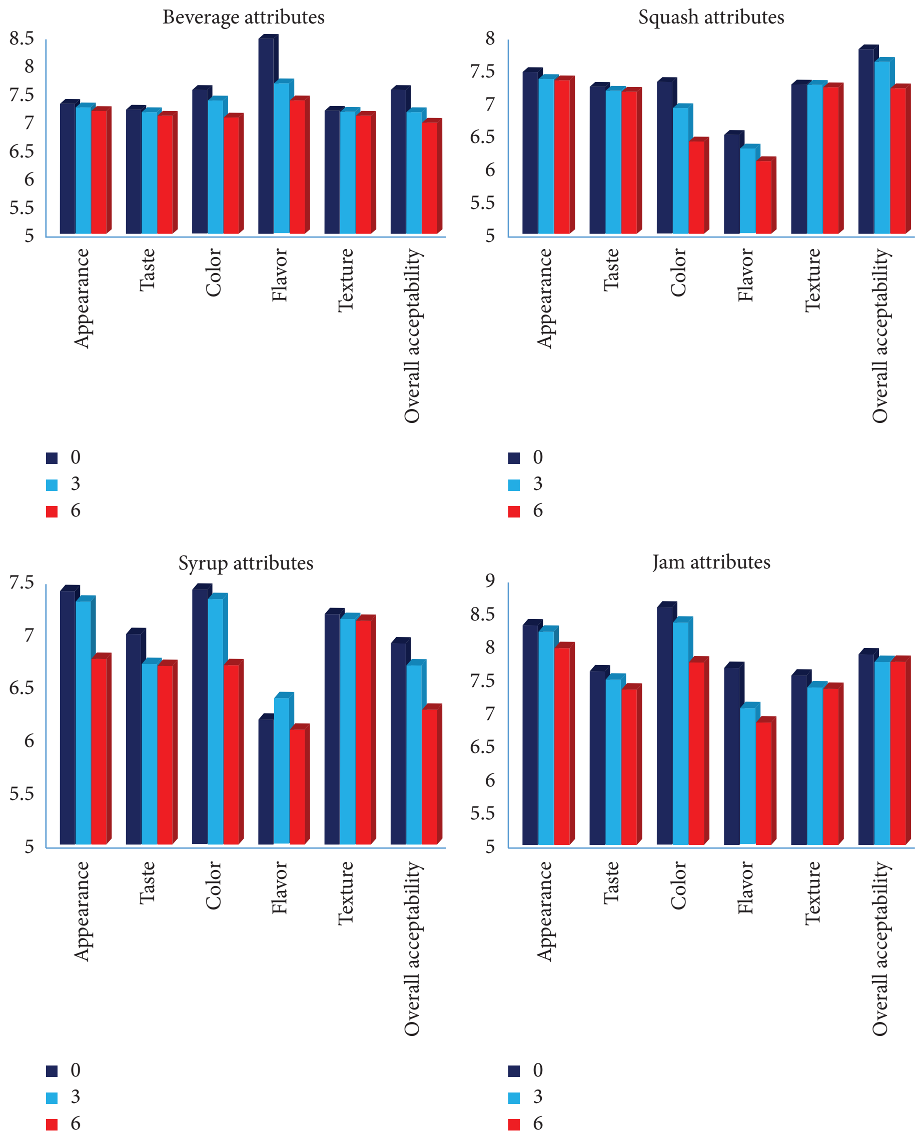

Figure 1: Sensory qualities of jamun products during storage.

Jam had the highest anthocyanin retention after six months of storage, followed by syrup and squash. This might be explained by the jam's high sugar content, which may have aided to preserve the anthocyanin pigment.

(5) Total Phenolic Content. The results displayed in Table 8, revealed that beverage had the highest TPC (351 mg GAE/100 g) followed by squash (222.14 mg GAE/100 g), syrup (172.18 mg GAE/100 g) then jam (153.11 mg GAE/100 g). With storage, TPC dropped considerably and reached 301, 192.31, 136.1, and 136.15 mg GAE/100 g. Bhatt et al. [55] and Gomez et al. [3] all noted a comparable decrease in TPC in jam, squash, and nectar produced from jamun fruits. The reduction in phenols with storage may be caused by their decomposition into sugar, acid, and other components or by their transition from soluble to insoluble forms throughout processing or storage. This drop in phenols also might have occurred as a result of heat and oxidative deterioration that caused polyphenols to polymerize [42].

(6) Total Antioxidant Activity (%). Plant metabolites such as phenolic components, carotenoids, ascorbic acid, and vitamin E are among the important bioactive molecules giving antioxidant activity. Greater concentrations of these molecules in fruits, vegetables, and their processed products are markers that food samples have better health-protective qualities. Syrup and jam had lower antioxidant values on zero day (51.65 and 48.55%), while beverage and squash had higher antioxidant values (63.44 and 53.22%). With the progression of storage, the antioxidant activity of the jamun fruit products revealed a significant ($P < 0.05$) decreasing pattern (Table 8). TPC, total anthocyanins, and ascorbic acid were partially destroyed as a result of thermal and oxidative degradation during the manufacturing of the product, which is what caused the reduction in the products. Despite a large decline, the antioxidant % of beverages, squash, syrup, and jam, respectively, were found to be retained to an average of 55.45, 50.33, 45.22, and 43.67%. Zhang et al. [61] showed a similar decline in radical

scavenging activity during storage in processed blueberry products.

3.3. Sensory Properties of Jamun Fruits Products during Storage. The sensory quality of jamun products determines their storage stability (beverages, squash, syrup, and jam). These products' sensory qualities were evaluated in terms of their appearance, taste, color, flavor, texture, and general acceptability (Figure 1). Jamun jam appearance received the highest rating (8.33), followed by squash (7.45), syrup (7.39), and beverage (7.33), all of which had a good sensory quality.

The jamun jam received the highest rating for taste (7.65 at zero time). While all jamun products had acceptable sensory quality, the syrup received the lowest score (6.99). The product's hue serves as the initial indicator of its identification and frequently serves as a forecast of the level of satisfaction or pleasure that will be experienced while consuming it [20].

The results showed that jamun jam had the highest color score (8.6), followed by beverage (7.6) and syrup (7.4), then squash (7.3). The anthocyanin pigment in the fresh jamun fruit may be responsible for the high color values of jamun jam. The jamun beverage received the highest sensory scores for flavor (8.5 at zero time), whereas squash received the lowest (6.5). Jamun jam (7.6) received the highest texture grade at zero time. The syrup, on the other hand, received the lowest rating (6.99). Jam, squash, and beverage all received overall acceptability scores of 7.9, 7.8, and 7.6, respectively, while the syrup sample had the lowest overall acceptability rating (6.9).

All sensory scores were observed to gradually decline throughout storage. The loss of volatile aromatics, the deterioration of ascorbic acid and furfural synthesis, or the use of heat during processing, may result in increasing the loss of flavor and taste scores [62, 63]. The product's loss in taste, appearance, color, and flavor over storage may be the cause of the overall acceptance scores declining. Similarly to this, Bhatt et al. [55] reported that organoleptic quality decreased with storage. Degradation of anthocyanin, ascorbic acid, TPC, and changes in the pH, maybe cause a decline in the sensory property. Finally, even after six months of storage at room temperature, the jamun fruit products contained were still acceptable.

4. Conclusions

The jamun fruit is renowned for its therapeutic benefits and for being a good source of minerals, natural colorings, and antioxidants. This fruit is still underused commercially despite its many advantages. This study set out to examine the jamun fruit's hylic and its characteristics. Use the jamun fruits to prepare jam, syrup, squash, and beverage with improved nutritional and sensory attributes to potentially open up a new export market. Jamun fruits showed 17.56 °Brix, 3.63 pH, 328.50 mg cyd-3-Glu/100 g anthocyanin, 219.21 mg GAE/100 g total phenolics, 91.33 mg QE/100 g total flavonoids, and 91.33% antioxidant activity. Jamun fruits had higher contents of K, P, Mg, Ca, Mn, and Fe. Jamun products showed a high amount of phytochemicals during room storage. Overall, jamun is a fruit that shows potential for providing valuable items in the future. All jamun fruit products fulfilled good criteria and were palatable to the senses.

Data Availability

The data used to support the findings of the study are included in the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

Samia El-Safy, and Ibrahim M. Taha as equal contributors.

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