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Green Valorisation Of Underutilized Jamun (Syzygium Cumini) Seed: A Novel Source Of C-Type Resistant Starch For Food And Nutraceutical Applications

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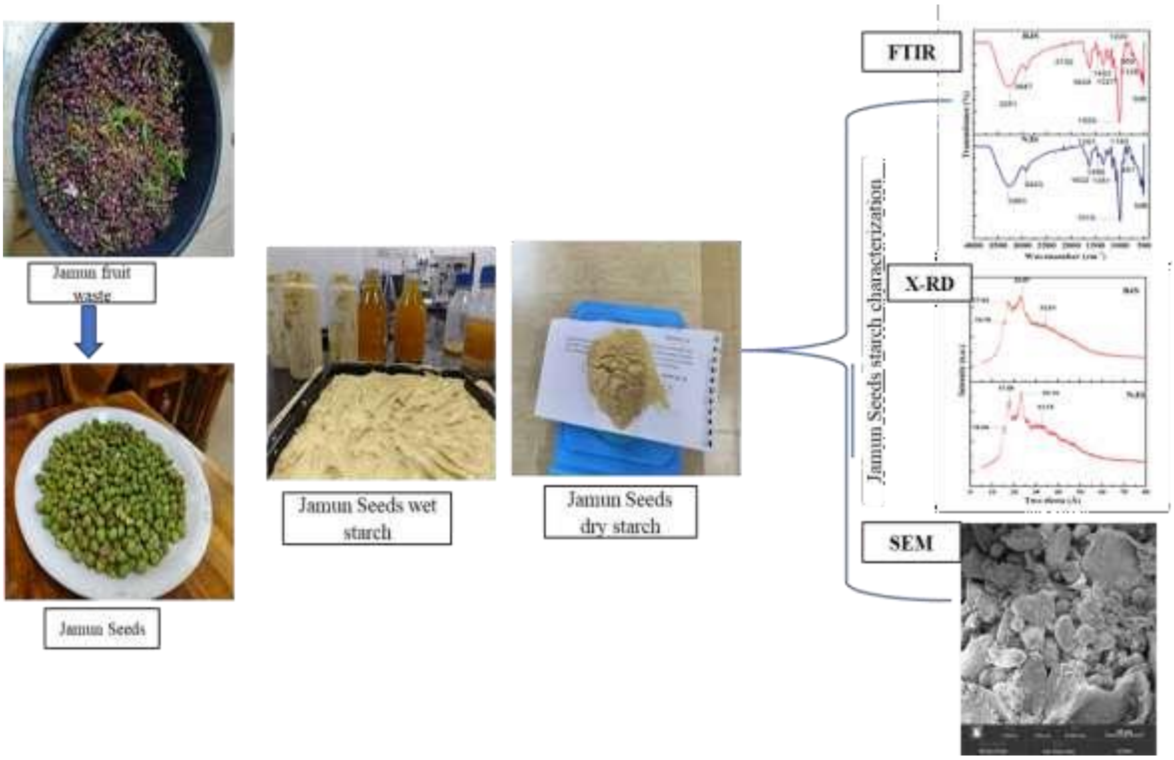
Abstract:
The growing demand for sustainable and functional food ingredients has driven research into alternative starch sources. This study focuses on the isolation and characterization of starch extracted from underutilized jamun (Syzygium cumini) seeds, aiming to evaluate its potential applications in the food and nutraceutical industries. Native starch (NJS) was isolated through aqueous extraction and subjected to hydrothermal modification via boiling to obtain boiled jamun seed starch (BJS). Both forms were analysed for amylose content, solubility, swelling power, thermal properties, morphology, and crystallinity using standard techniques including AOAC methods, scanning electron microscopy (SEM), and X-ray diffraction (XRD). Results showed a high amylose content (26.55 ± 0.02%), with boiling significantly enhancing solubility and reducing retrogradation tendency. SEM revealed irregular granular morphology, while XRD indicated a C-type crystalline pattern. Thermal analysis demonstrated a shift in gelatinization temperatures due to boiling. These findings suggest that jamun seed starch, especially in its modified form, possesses favourable physicochemical and functional properties suitable for diverse applications. By valorizing jamun seed waste, this research contributes to sustainable ingredient development and opens new avenues for functional food formulation.
Keywords: *Syzygium cumini, Jamun seeds, Starch, Antidiabetic and Antioxidant*



INTRODUCTION

A key food source for humans is starch, a readily accessible and renewable carbohydrate mostly made up of amylose and amylopectin. Cereals including wheat, corn, rice, and oats include starch, which is used as an energy storage substance. Some physicochemical properties of native starch (NS), such as pasting qualities, thermal stability, and paste transparency, are insufficient due to a lack of specific functional groups in its molecular structure, preventing it from satisfying manufacturer requirements.[1] Starch is broadly treated with some pretreatment to get other starch modifications before using in industrial production as a material of various properties hence requirement. Various strategies (either physical, chemical or enzyme modification) were used for starch molecule tailoring to achieve viscosity property of interest[2] Starch, as a biodegradable and non-toxic biopolymer, is widely distributed in parts from plants such as the grains, seeds, fruits, roots and tubers.[3] Starch is one of the major natural sources of carbohydrates for human nutrition and is of great technological relevance not only in food industry but also for a number of non-food areas (e.g synthetic diets, pharmaceutical products and papers & adhesives.[4] Consideration of starch in industries is also determined by its chemical nature, gelatinization temperature, gelation capacity and paste viscosity. In addition, botanical peculiarities influence its potential industrial use like the ratio of amylose and amylopectin, and often extraction processes modifying technological behaviour.[5]Jamun fruit is generally agreed on as great for medicinal use specially when it comes too diabetes due to its action on pancreas. Fruit and seed contain glucoside jamboline, ellagic acid, which has been found to inhibit the excessive sugar-starch convertional pathway, Glucoside Jamboline also possess antibacterial properties of jambul fruits Seed is believed to check starch to sugar conversion in case there is an excess sugar production, The nutraceutical constituents of fruit are resin, albumen, gallic acid, essential oil and tannic acid. Also jamun fruit is a very good home remedy for piles and for bleeding piles or liver indigestion. Even has the ability to prevent diarrhoea, pharyngitis and splenopathy. It can be used in conditions such as Jugular venous insufficiency (large spleen), Chronic diarrhoea and bladder dysfunction (urine retention). Seeds are used in many other systems of medicines like Ayurveda, Unani and Chinese medicine. The plant has medicinal properties such as controlling hyper tension, gingivitis etc. on the barks and leaves.Ayurvedic medicine has long utilized jamun (Syzygium cumini) seeds, which are high in bioactive chemicals, to treat digestive issues and diabetes. Numerous pharmacological characteristics, such as antibacterial, antioxidant, and antidiabetic effects, have been validated by contemporary research.[6-8] The in vivo significance of these features is being studied, especially in the treatment of gastrointestinal diseases and skin cancer. Early research mainly concentrated on the hypoglycemic potential of jamun seed extracts; this was later extended to include cardioprotective actions,[9] immunomodulatory effects,[10] lipid-lowering effects,[11] and neuro-psychopharmacological benefits.[11] Numerous phytochemicals, including phenolics, terpenoids, saponins, and derivatives of phloroglucinol, are responsible for these actions. To comprehend these components' modes of action and possible uses in functional food and nutraceutical formulations, more research is essential. Massive studies are being conducted on biological potential and seed extracts, fractions and isolated compounds are being assessed for their antidiabetic, antiooxidant, anti-inflammatory, anticancerous, antimicrobial, cardioprotective hepatoprotective and neuroprotective activities. In addition, jamun seeds are packed with nutrients They are high on carbohydrates, dietary fiber, vitamin C and some minerals.[12] The nutritional and phytochemical profiles of jamun seeds suggest that they might be used as a novel source for pharmaceutical and food industries. In terms of the present review, the nutrients and phytochemicals of jamun seeds are taken as background information which is related to the bioactive properties of this resource from where the processing by-product of a jamun fruit can be used in functional food formulation.

MATERIALS AND METHODS

Jamun seeds were gathered at GITAM University Campus in Visakhapatnam, AP, India, for testing purposes. The seeds were then thoroughly cleaned to eliminate any contaminants.

Starch extraction:

Decorticated Jamun seeds were soaked in deionized water for about 4 to 6 hours. The seeds were then ground with five times their weight in water using a tabletop wet grinder. The resulting slurry was filtered through sieves of 105 µm, 75 µm, and 45 µm sizes. The starch collected was washed with distilled water, treated with diluted NaOH, and washed again with distilled water. It was then centrifuged at 5000 rpm. The final starch sediment was collected and dried at 45 °C for 12 hours.[13]

Chemical composition analysis:

The moisture and ash content of the isolated starches were measured using the AOAC[14] method. Crude protein was estimated with the Kjeldahl method, as outlined in AOAC.[15] The fat content in the starch samples was determined using the Soxhlet extraction method, following AOAC.[15] Amylose levels in the starches were measured according to the procedure described by Ratnayake et al.[16] The amylose content was then calculated using a standard amylose curve.

Functional properties

Water and Oil absorption capacity:

The water and oil absorption capacity (WAC) of the starch samples was measured using the method by Abbey and Ibeh.[17] First, 1 gram of starch was mixed with 10 mL of distilled water or oil in a centrifuge tube. The mixture was left to stand for 30 minutes. Then it was centrifuged at 3000 rpm for 15 minutes. After centrifuging, the liquid was removed, and the remaining residue was weighed. The increase in weight of the sample was recorded as the water absorption capacity in milliliters per gram (mL/g).

Swelling power and solubility:

The swelling power of starch was measured using the Leach, et al.[18] method throughout a temperature range of 50 to 90 °C with a 10 °C interval.

Paste clarity:

The paste clarity was assessed using a modified version of R. Devi et al.[19] methodology. 1% (w/w) distilled water was used to suspend the starch sample. The suspensions were then cooked in a boiling water bath for 30 minutes while being continuously stirred, and they were thereafter allowed to cool to room temperature. Using water as the control, the UV spectrophotometer was used to measure the light transmittance T (%) of starches at 620 nm.

Bulk density:

In accordance with the methods described by Joshi & Rao,[20] the samples were gently tapped in a graduated measuring cylinder to determine the bulk density. To obtain the tapped density, the same sample was then gently tapped 50 times in total. The Hausner Ratio (HR) and Carr Index (CI) were used to measure the flour's cohesion and flowability, respectively. These figures were calculated using the formula given by Hao. [21]

Scanning electron microscopy (SEM):

Scanning electron microscopy (SEM): SEM (Tescan, VEGA 3, Brno, Kohoutovice, Czech Republic) was used to analyze the surface topography of starch samples. During operation, an acceleration potential of 15 kV was applied.

X-ray diffraction (XRD) and FT-IR spectroscopy: For FT-IR analysis, a starch sample was made using the pellet technique. Using this approach, 0.5 g of potassium bromide was combined with a few milligrams of the starch. The mixture was formed into a 13 mm pellet by applying 20 psi of pressure. The pellet was positioned in the spectroscope's sample holder between the interferometer and detector. The FT-IR analysis was performed with a scanning range of 4000–500 cm^{-1} at a resolution of 2.0 cm^{-1} using a FT-IR spectrometer (Perkin Elmer, USA).

Statistical analysis: The mean and SD were calculated for the data shown in the tables, which were performed in triplicate. Student t-test ($P < 0.05$) was performed using SPSS 20 software.

Results and discussion

Moisture Content

Moisture content of jamun seed starch present at Table 1. The moisture content of native jamun seed starch (NJS) was found to be 13.42 ± 0.02%, which significantly decreased to 11.43 ± 0.63% upon boiling (BJS). This reduction can be attributed to moisture evaporation during the thermal treatment. Boiling is known to reduce moisture levels in food matrices, as heat facilitates the escape of bound and free water molecules. A similar trend was reported by Raza et al. [22], who observed a moisture content of

16.34 ± 0.49% in unprocessed jamun seeds. The variation among studies may arise from differences in drying techniques, environmental storage conditions, and seed maturity levels.

Ash Content

Ash content of jamun seed starch present at Table 1. Ash content, indicative of total mineral content, showed a slight decline from 2.53 ± 0.37% in NJS to 2.35 ± 0.59% in BJS. However, this change was not statistically significant. Boiling may cause minimal leaching of minerals, particularly those soluble in water. Rachappaji and Salimath [23] reported an ash content of 2.93% in jamun seeds, which is slightly higher than the values in the present study. Discrepancies could result from differences in soil composition, geographical origin, and agricultural practices.

Protein Content

Protein content of jamun seed starch present at Table 1. The protein content decreased from 5.84 ± 0.64% in NJS to 4.93 ± 0.42% in BJS. This reduction, although not statistically significant, might be due to partial denaturation or leaching of soluble proteins during boiling. Prior studies have shown a range of protein contents in jamun seeds, typically between 4.7–8.2% (Raza et al)[22], depending on varietal and environmental factors. Heat processing may impact the structure and solubility of proteins, explaining the slight reduction observed here.

Crude Fat Content

Crude fat content of jamun seed starch present at Table 1. An increase in crude fat content was observed after boiling, from 2.71 ± 0.73% in NJS to 3.73 ± 0.87% in BJS. This rise may be attributed to the breakdown of structural barriers during boiling, which can enhance the extractability of lipids. Interestingly, Raza et al.[22] reported a much lower fat content (0.65 ± 0.01%) in jamun seeds, potentially due to different extraction solvents or mechanical methods used. This highlights the sensitivity of fat yield to methodological variations.

Amylose Content

Amylose content of jamun seed starch present at Table 1. The amylose content exhibited a significant increase from 7.74 ± 0.14% in NJS to 13.05 ± 0.02% in BJS. The increase is likely due to heat-induced gelatinization and partial hydrolysis of starch granules, which facilitates the release of amylose chains. While limited literature is available specifically on jamun seed starch, similar thermal effects on amylose levels have been documented in cereals and tuber starches. This suggests a generalizable effect of thermal processing on starch molecular structure[24].

Table 1 Proximate composition of jamun seed starch.

Properties	NJS (Mean ± SD)	BJS (Mean ± SD)
Moisture (%)	13.42 ±0.02	11.43±0.63
Ash content (%)	2.53±0.37	2.35±0.59
Crude protein (%)	5.84±0.64	4.93±0.42
Crude fat (%)	2.71±0.73	3.73±0.87
Amylose (%)	7.74±0.14	13.05±0.02

Water Absorption Capacity (WAC)

The water absorption capacity of BJS (8.38 ± 0.27 g/g) was significantly higher than that of NJS (6.88 ± 0.71 g/g). This indicates that BJS starch has a higher affinity for water, which may be attributed to the presence of more hydrophilic groups or differences in granule size and surface area. High WAC is desirable in food formulations where hydration is essential, such as in bakery and meat products.[25] Similar WAC values have been reported for starches from other underutilized plant sources like breadfruit and jackfruit seeds.[26] This difference may be attributed to variations in starch granule structure, amylopectin content, and the presence of hydrophilic groups. Recent studies have highlighted that the multi-scale structure of starch significantly influences its water absorption behaviour. Directional modifications can alter WAC, affecting the performance of starch in food applications. High WAC is beneficial in products like sauces and jams, where moisture retention is crucial.[27]

Oil Absorption Capacity (OAC)

NJS showed higher oil absorption capacity (0.086 ± 0.002 g/g) compared to BJS (0.055 ± 0.005 g/g). OAC is influenced by the protein and lipid content of starch, with non-polar side chains binding more oil. The lower OAC of BJS suggests a more hydrophilic nature or lower lipid content, which could affect its use in flavor retention and mouthfeel in food systems.[28] Similar trends have been noted in yam and canna starches.[5] The formation of starch–lipid complexes have been shown to significantly reduce oil absorption, with the complexing index inversely related to oil uptake. Such properties are essential in developing healthier fried foods with reduced oil content.[29]

Bulk Density

Bulk density values for NJS (1.26 ± 0.15 g/cm*) and BJS (1.21 ± 0.18 g/cm*) were comparable, indicating similar packing behaviour and particle compactness. This property affects packaging and transportation and is particularly important in powdered food applications.[30] The values align with those reported for starches extracted from legume and tuber flours.[31] Bulk density affects packaging and transportation and is particularly important in powdered food applications. Studies on cassava starch foams have shown that amylose content can influence foam density, with higher amylose leading to denser structures.[32]

Foaming Capacity

The foaming capacity was low for both starches: NJS (3.87 ± 0.03%) and BJS (3.83 ± 0.02%). This is consistent with the generally poor foaming ability of pure starches, which lack the amphiphilic proteins necessary for foam formation and stabilization.[33] Therefore, these starches may not be ideal for aerated food systems but could still be used in formulations where minimal foaming is desired. This is consistent with the generally poor foaming ability of pure starches, which lack the amphiphilic proteins necessary for foam formation and stabilization. However, the incorporation of starch into foam systems has been explored for applications like active packaging, where starch-based foams can provide oxygen-controlled release and cushioning properties.[34]

Paste Clarity

NJS showed slightly higher paste clarity (44.62 ± 1.13%) compared to BJS (43.16 ± 0.70%), suggesting marginal differences in the retrogradation behaviour and amylose leaching of the starches. Higher clarity is often associated with lower amylose content and higher solubility, making NJS more suitable for applications such as transparent sauces and gels.[35] Paste clarity is influenced by factors such as amylose content and granule integrity. Higher clarity is often associated with lower amylose content and higher solubility, making NJS more suitable for applications requiring transparent gels and sauces. Recent research has emphasized the role of starch composition in determining the optical properties of starch pastes, which is critical in food product development.[36]

Table 2: Functional properties of jamun seed starch.

Properties	NJS (Mean ± SD)	BJS (Mean ± SD)
Water absorption capacity (g/g)	6.88±0.71	8.38±0.27
Oil absorption capacity (g/g)	0.086±0.002	0.055±0.005
Bulk density (g/cm)	1.26 ± 0.15	1.21 ± 0.18
Foaming (%)	3.87±0.03	3.83±0.02
Paste clarity (%)	44.62±1.13	43.16±0.70

The swelling power of native jackfruit seed starch (NJS) and boiled jackfruit seed starch (BJS) was evaluated at temperatures ranging from 40 °C to 90 °C. The results, presented in the table below, indicate distinct swelling behaviours for the two starch samples:

Table 3: Swelling power of jamun seed starch.

Temperature (°C)	NJS (Mean ± SD)	BJS (Mean ± SD)
40	2.61±0.17	4.61±0.70
50	3.02±0.51	5.35±0.75
60	4.13±0.65	6.38±0.53
70	5.25±0.41	8.79±0.93
80	10.97±0.60	7.90±0.84
90	13.96±0.54	7.36±0.77

At lower temperatures (40 °C–70 °C), BJS exhibited significantly higher swelling power than NJS. For instance, at 70 °C, BJS reached 8.79 g/g compared to 5.25 g/g for NJS. This suggests that the boiling pre-treatment may have disrupted the granular structure of starch, facilitating water uptake and early gelatinization. Boiling likely weakened the crystalline regions, thus enhancing hydration at lower temperatures. However, a contrasting trend was observed at higher temperatures (80 °C–90 °C), where NJS showed a sharp increase in swelling power, reaching 13.96 g/g at 90 °C. In comparison, BJS showed a decline in swelling power beyond 70 °C, decreasing to 7.36 g/g at 90 °C. This decline in BJS may be attributed to partial gelatinization or retrogradation during the boiling process, leading to re-aggregation of starch molecules which limits further swelling. The thermal stability of swelling in NJS indicates a more intact granular structure that resists breakdown until higher temperatures are reached. On the other hand, the peak and subsequent decline in BJS suggest its susceptibility to thermal degradation or molecular reassociation at elevated temperatures. Examines how boiling affects starch structure and swelling, showing decreased swelling capacity at higher temperatures due to molecular reassociation.[37] This review highlighted that native water chestnut starch exhibits excellent swelling power due to its structural characteristics. However, modifications such as acid treatment and pregelatinization significantly decreased its swelling power. The study emphasizes how different treatments can alter the physicochemical properties of starch, including its ability to swell.[38] The solubility of NJS and BJS samples was evaluated across six conditions, potentially representing increasing temperatures, time points, or solvent concentrations (specific conditions should be clarified). The results are presented in **Table 1**. Overall, both samples exhibited an increasing solubility trend, indicating improved dissolution or dispersion characteristics under the applied conditions.

Table 3: solub ility of jamun seed starch.

Temperature (°C)	NJS (Mean ± SD)	BJS (Mean ± SD)
40	2.12 ± 0.19	2.61 ± 0.43
50	2.78 ± 0.25	4.02 ± 0.51
60	3.80 ± 0.89	5.05 ± 0.67
70	5.58 ± 0.23	7.82 ± 0.87
80	7.14 ± 0.63	7.50 ± 0.61
90	6.96 ± 0.47	6.69 ± 0.70

The **BJS** sample consistently demonstrated higher solubility than **NJS** across all tested conditions. For example, at condition 4, BJS reached 7.82 ± 0.87 mg/mL compared to 5.58 ± 0.23 mg/mL for NJS. This suggests that BJS may possess superior physicochemical properties conducive to solubilization. The enhancement in solubility could be attributed to differences in molecular structure, particle size, surface area, or formulation strategies such as the inclusion of solubilizers or surfactants. Interestingly, solubility plateaued or slightly declined at condition 6 for both samples, which might indicate saturation or aggregation effects at higher concentrations or unfavorable thermodynamic conditions. Similar solubility behavior has been observed in previous studies where solubility increased with temperature or solvent polarity but reached a peak before declining due to compound instability or recrystallization.[39]From a formulation perspective, the superior solubility of BJS suggests its potential for improved bioavailability and therapeutic efficacy. Enhanced solubility is often correlated with better absorption, particularly for compounds with limited aqueous solubility.[40]

Scanning Electron Microscopy (SEM)

Figure 1 presents the FESEM micrographs of starch samples: Native Jamun Seed (NJS) and Boiled Jamun Seed (BJS). The microstructural differences provide insight into the impact of processing treatments on starch granule morphology. **Native Jamun Seed Starch (NJS)**, the starch granules exhibit a compact, dense structure with irregular shapes. The surface appears relatively smooth with fewer signs of disruption, indicating intact native granules. **Boiled Jamun Seed Starch (BJS)**, boiling leads to significant morphological changes. The granules show signs of swelling, disruption, and partial gelatinization. The surface appears rougher and more fragmented compared to NJS, suggesting partial breakdown of the granular structure due to heat and moisture exposure. These microstructural observations are consistent with the expected effects of thermal processing, where moist heat (boiling) causes swelling and partial gelatinization, while dry heat (roasting) leads to more severe degradation and structural modifications. Such morphological changes can significantly influence the functional and physicochemical properties of the starch, including solubility, swelling power, and digestibility, which are crucial for food and nutraceutical applications. Abiddin et al.[41] observed similar findings. The spray-dried pre-gelatinized starches (sweet potato, Peruvian carrot, cassava, and corn starches) have a shriveled surface, regular form, and hollow structure, according to Hao Ma et al.[42] Its spherical particles can increase the fluidity of solids, and its average particle size is lower than that of native starch.[43]

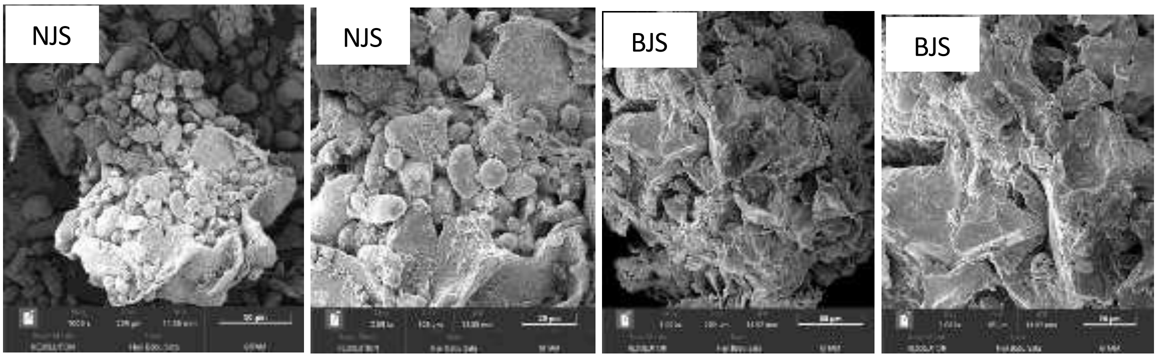


Fig. FESEM Images of jamun seed starch

X- ray diffraction (XRD)

XRD analysis was carried out to elucidate the crystalline structure and the impact of thermal treatment on jamun seed starch. The diffraction patterns for both native (NJS) and boiled (BJS) starch samples show distinct differences, indicating structural modifications. The NJS pattern exhibits prominent peaks at 2θ = 15.04°, 17.65°, 23.13°, and 31.73°, characteristic of A-type crystallinity, which is commonly found in cereal starches. These sharp peaks reflect a well-defined crystalline arrangement of starch molecules in their native state.[44-46] In contrast, BJS displays peaks at 2θ = 14.78°, 17.91°, 22.87°, and 33.81°. The shift in peak positions and broader profiles suggest a partial transformation from A-type to a more disordered or C-type pattern, potentially due to the thermal disruption of crystalline lamellae during boiling. The appearance of a broader peak around 22.87° in BJS, relative to the sharper peak at 23.13° in NJS, implies a reduction in crystallinity.[47,48] After boiling, these peaks disappeared, as seen in Fig. 9, meaning the crystalline structure in the starch had been lost. Similar results have been reported for other types of modified starches.[49]This thermal processing likely caused partial gelatinization, disrupting the crystalline double helices and leading to reorganization into less ordered forms. These changes are significant, as they can enhance resistant starch formation and alter digestibility, water retention, and retrogradation behaviour, beneficial for functional and nutraceutical applications. Hence, the XRD results corroborate FTIR findings, demonstrating that boiling significantly impacts the crystalline architecture of jamun seed starch, shifting its molecular organization and potentially improving its application in health-targeted food systems.

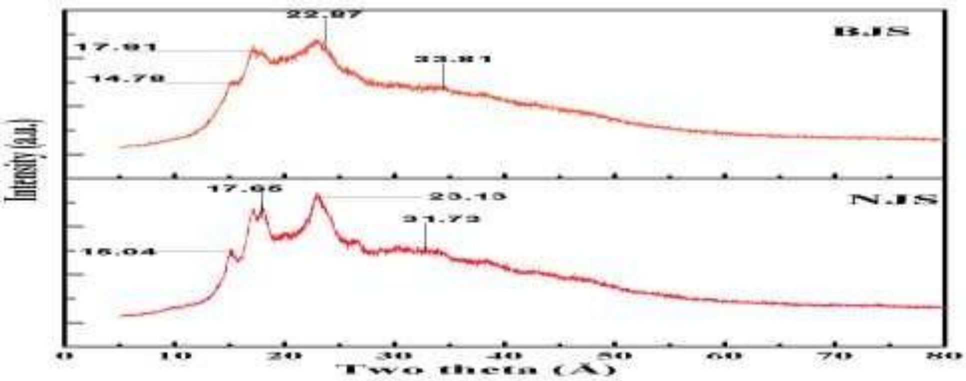


Fig. 2. XRD curves of native and modified starch samples.

Fourier Transform Infrared Spectroscopy (FTIR)

FTIR spectroscopy was employed to investigate the structural modifications in jamun seed starch before (NJS) and after boiling (BJS). The observed spectra reflect distinct changes in functional group vibrations, indicating physicochemical transformations. The broad absorption bands around 3263 cm^{-1} (NJS) and 3251 cm^{-1} (BJS) correspond to the –OH stretching vibrations, which are characteristic of inter- and intramolecular hydrogen bonding in starch. The slight shift toward a lower wavenumber in BJS indicates increased hydrogen bonding, possibly due to gelatinization and rearrangement during boiling. The C–H stretching peaks were noted at 2923 cm^{-1} (NJS) and 2947 cm^{-1} (BJS), with an increased intensity in BJS, suggesting greater exposure of aliphatic chains post-boiling. Significant differences were observed in the fingerprint region (1200–500 cm^{-1}). In BJS, the bands at 1222, 1128, 1022, and 869 cm^{-1} were more defined, indicating the formation of ordered structures, potentially linked to C-type crystallinity and resistant starch formation. NJS, on the other hand, exhibited broader peaks in this region, reflecting a more amorphous structure. Additionally, the peak at 1632 cm^{-1} (NJS) and its shift to 1620 cm^{-1} (BJS) signifies changes in bound water or amorphous content due to processing. The persistence of the band at 506 cm^{-1} in both samples confirms skeletal modes of the polysaccharide backbone, which remain unaffected by boiling. Overall, the FTIR spectra confirm that boiling induces structural reorganization in jamun seed starch, leading to increased hydrogen bonding and a more ordered crystalline pattern. These modifications suggest a potential increase in resistant starch content, which is beneficial for developing functional or nutraceutical food ingredients. Similar trends have also been reported by Liu, T et al.[50] for potato starch and Imtiaz Ali et al.[51] tapioca starch. Huijing Chen, et al.[52] who reported that wheat starch had similar results. Some bands in the range of 1100–900 cm− 1 indicated that the presence of C–O stretching in the C–O–C and C–O–H of starch glycosidic became weak in boiled (modified) starch, suggesting that modification greatly damaged the starch's fine structure.[53] The absorption intensity ratio at 1010/1022 cm−1 revealed the short-range order degree of starches, and the bands at 1010 and 1022 cm−1 are often sensitive to changes in amorphous and ordered starch structures. Those at 1010 cm−1 of BJS 1022 cm−1 reduced in comparison to the ratio of NJS, indicating that the newly inserted OS groups had damaged the starch molecular chain. The decreasing tendency of the initial fine structure of starch becomes increasingly apparent when additional groups are added. The FTIR ratios of pregelatinized starch reduced, according to Garcia-Valle et al.[54] This might be because partial gelatinization and swelling disturb the structure of the starch granules.

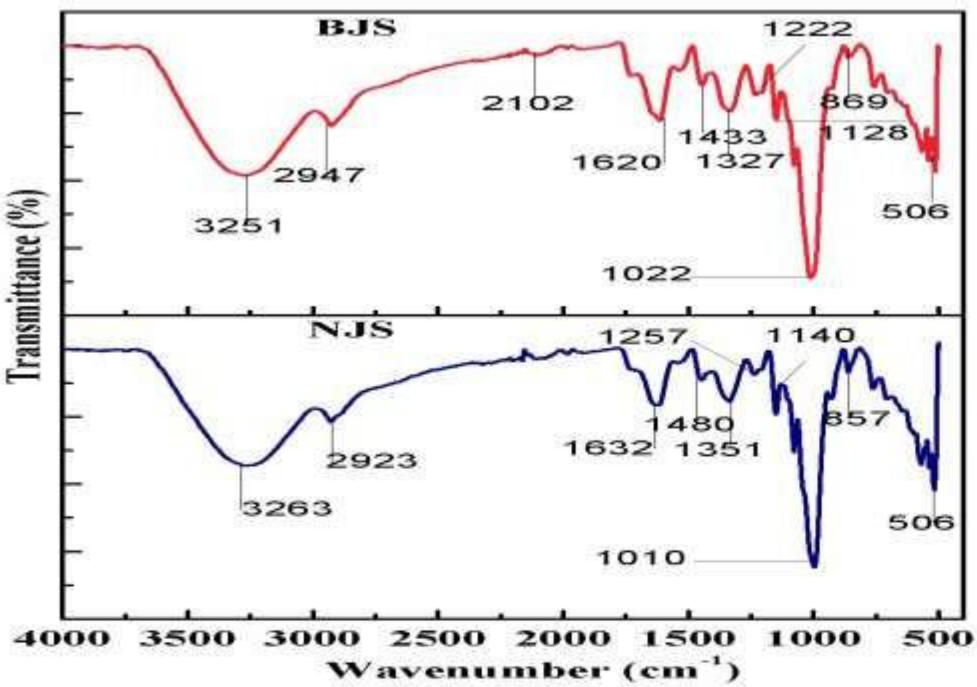


Fig. 3. FTIR Spectra of native (NJS) and modified starches (BJS)

CONCLUSIONS

This study successfully demonstrated that jamun (Syzygium cumini) seeds, an often-discarded agro-waste, are a promising and sustainable source of starch with distinct physicochemical and functional characteristics. The native starch exhibited high amylose content, while hydrothermal modification through boiling significantly improved its solubility and altered its thermal behaviour making it more suitable for specific industrial applications. The morphological and crystalline analyses revealed unique structural features, with a C-type crystallinity uncommon among conventional starch sources. These properties suggest that jamun seed starch, particularly in its modified form, holds considerable potential for use as a functional ingredient in clean-label foods, biodegradable films, and controlled-release nutraceutical systems. The valorization of jamun seeds not only addresses food industry demands for novel starches but also promotes waste utilization and circular bioeconomy practices. Future work may explore enzymatic or dual modifications to further enhance its applicability across food and pharmaceutical sectors. This research pioneers a new pathway in functional starch innovation, encouraging the exploration of other underutilized botanical resources for next-generation ingredient development.

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