AATCC Review

11 April 2025: Received
01 June 2025: Revised
08 June 2025: Accepted
10 July 2025: Available Online

https://aatcc.peerjournals.net/

Original Research Article

Open Access

Phyisco-Chemical and Structural Characterization of Starch Extracted from Red and White Rice obtained from North-West Himalayas

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ABSTRACT

The study aimed to analyze the starch extracted from red and white rice physico-chemically and structurally. The alkaline steeping procedure was utilized to extract the starch. Alkaline extraction is the most effective method for extraction of starch from rice, yielding an impressive 70% of the total starch. The extraction yield was found to be 58% and 65%, in white rice and red rice, respectively. The results revealed red rice contained moisture 11.80%, ash 0.50%, crude fat 0.51%, crude protein 0.32%, water absorption 109 g/100g^{-1}, oil absorption 76.60 g/100g^{-1}, starch 82.50% and amylose 25.71 % whereas in white rice moisture was 11.20%, ash 0.25%, crude fat 0.34%, crude protein 0.46%, water absorption 81 g/100g^{-1}, oil absorption 56.60 g/100g^{-1}, starch 86.33% and amylose 17.23%. The peak of crystallinity degree obtained in XRD of red rice was 19 ɵ and white rice was 20 ɵ, respectively. The FTIR results revealed the peak of maximum intensity spectral bands at red rice 1012.77cm^{-1} and 998.62cm^{-1} of white rice. This study compares the physicochemical properties of red and white rice starches using FTIR, XRD, proximate composition, amylose content, starch yield, and water/oil absorption capacities. Despite challenges like compositional variability and limited red rice data, we identified distinct differences in amylose content and crystallinity, influencing functional properties. Red rice starch showed higher yield and unique molecular traits, suggesting suitability for health-focused products. These findings bridge knowledge gaps, support rice breeding, and promote red rice for sustainable food applications.

Keywords: *alkaline, extraction, yield, starch, red rice, white rice.*

Introduction

Rice is a major cereal crop consumed as a staple food by over half of the world's population. In the year 2024 the production volume of rice was found nearly 138 million metric tonnes in India. The first advance estimate for the year 2025 indicates rice production around 120 million [1]. More than half of all production worldwide is produced by the top two countries. China and India produced 28 (211.4 million tons) and 23.5 per cent (177.6 million tons) of total rice production in the world (2019) as per the data from the UN's FAOSTAT and the USDA [2]. Rice is predominantly made up of starch, which constitutes an impressive 90% of the dry weight of polished rice [3]. Starch is the major component of rice grains and an important ingredient in many food and industrial products. Rice starch consists of very small granules (5 mm) with a narrow size distribution, it is white in colour and bland in flavour, which makes it ideally suited as a cosmetic dusting powder, paper powder, coating in confectionery, and excipient for pharmaceutical tablets [4].

Red rice, referred to locally as Zag due to its distinctive coloured kernels, is a traditional landrace variety cultivated in Jammu and Kashmir. This rice exhibits a characteristic coloured pericarp and is recognized for its superior nutritional quality [5].

Red rice contains more nutritional and bio-functional components than common whole rice, including proanthocyanidins, γ-aminobutyric acid, γ-oryzanol, dietary fibres, vitamins, and minerals [6]. Pigmented rice varieties (Oryza sativa) have a high concentration of starch, protein, minerals and B vitamins including health-promoting phytochemicals such as anthocyanins, pro-anthocyanidins and carotenoids, thus giving high nutritional quality [7]. The production of rice starch incurs higher costs than other types of starches due to the relatively high expense of rice as a cereal grain. Additionally, rice starch is intricately linked with rice protein bodies, contributing to its overall production costs [8]. The traditional approach includes solubilizing rice protein using an alkaline solution, whereas, the mechanical method releases starch from a wet milling process. These are the two most often used commercial methods for separating rice starch and protein [9].

White rice, which is milled and parboiled, is the type of rice that is commonly consumed. Nearly every zone, from subtropical to mid-hills to high hills (high altitudes), is represented in the Jammu region, making it a temperate zone. More than 32,000 hectares of land are used to grow basmati rice in the subtropical zone of the Jammu region. The Jammu region's basmati, especially from the R. S. Pura belt, is renowned worldwide for its powerful fragrance. Every year, the basmati rice industry brings in around 45 crores of rupees [10]. White rice contains essential vitamins and minerals such as vitamin D, potassium and magnesium and is an excellent source of manganese. It is primarily rich in carbohydrates and provides energy and is a good source of iron [11].

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DOI: https://doi.org/10.21276/AATCCReview.2025.13.03.369

Alkaline steeping is commonly used to isolate rice starch because the primary rice protein fraction, glutelin, is soluble in alkali [12]. The application of rice starch in the food industry is experiencing significant expansion, attributable to its beneficial characteristics. These include a low propensity to induce allergic reactions, a neutral flavour profile, stability of gel structure during freeze-thaw cycles, high digestibility, resistance to acidity, and specific contents of amylose and amylopectin. These attributes position rice starch as a valuable ingredient in various food formulations [13]. Therefore, the aim of the study is to extract and characterize the starch extracted from red and white rice, respectively.

Material and Methods

Extraction of starch

Extraction of starch was done by steeping in sodium hydroxide solution (0.2%) for 3 hours at room temperature as per procedure given by Lumdubwong and Seib, with slight modifications [14]. In this 20 g of sample was mixed with 50 ml of NaOH (0.2%) were filtered and centrifuged at 3000 rpm for 20 min. The supernatant was discarded and the sediment was washed twice with water and centrifuged at 3000 rpm for 20 minutes. It was then kept in water and pH was adjusted to 7 by adding 1M HCl and slurry was centrifuged at 6000 rpm for 10 minutes. The supernatant was discarded again and starch was carefully scrapped away. The starch was washed three times with water (50 ml) and was dried at 40^{0}C for 48h.

Chemical parameters

Moisture content was determined using an oven with air circulation at 105^{0}C until constant weight was obtained [15]. For ash, a sample of 1.5g was taken into a crucible of known weight. The crucible was ignited and transferred into a furnace and the sample left to ash [15]. The weighted ash was calculated. The crude fat content was determined by the Soxhlet extraction technique. The crude fat was determined [15]. The crude protein content was determined by the micro Kjeldahl method, using the factor 5.95 for converting nitrogen content into crude protein [16].

Extraction yield

Starch yield was calculated by the initial weight of the red rice and white rice and the final weight of the starch extracted from both rice divided by 100 [17].

$$\% \text{ of Extraction yield} = \frac{\text{Initial (wt)}}{\text{Final (wt)}} \times 100$$

Starch

To determine the starch content, a fresh sample weighing 0.1 to 0.5 g was homogenised in hot 80% ethanol followed by centrifugation at 10,000 rpm for 20 min. After that 5 ml of water and 6.5 ml of perchloric acid was added to the residue and refrigerated at 0^{0}C for 20 min. The residue was centrifuged again and the supernatant was saved for analysis. The final volume was made up to 100 ml and dilution was made in the ratio 1:5 using distilled water. 4 ml of anthrone reagent was added to each test tube and heated for about 8 minutes in a boiling water bath. The content was rapidly cooled and the intensity of green to dark green was read in UV visible spectrophotometer at 630 nm. A series of glucose working standards solutions (20-100 µg mL^{-1}) were used for calculating the starch content of both kinds of rice [18].

Amylose content

The amylose content was analyzed by using 10g of starch sample and 2ml of DMSO (Di-methyl-sulphoxide). The mixture was then heated at a temperature of 85^{0}C for 15 minutes. The addition of deionised water was done to make the volume up to 25 ml. The pipetting was done using 1 ml solution of starch solution followed by the addition of 5ml of iodine solution to reach 50 ml. The iodine regent was prepared by the addition of 2 g Iodine and 20 g potassium Iodide and volume was made up to 100 ml by distilled water. read at 620 nm and were expressed in 100g^{-1} of starch on dry basis [19].

Water and Oil absorption capacity

The water and oil absorption capacity of starches were determined by adding 20 mL of distilled water or soybean oil to 1 g of starch in centrifuge tubes. After homogenizing for 30 seconds and letting it rest for 30 minutes, the mixture was centrifuged for 15 minutes at 3000 rpm into liquid and solid phases. The absorption was measured in g/100 g (dry basis) [20].

$$\text{WBC/OBC (\%)} = \frac{\text{Weight of wet starch sample}}{\text{Weight of dry starch (g)}} \times 100$$

Fourier-transform infrared (FTIR) spectrophotometer

FTIR Spectrum was recorded using Perkin Elmer spectrum, IR spectra of rice starches in the region 0f 4000- 400cm^{-1} was used, with a resolution of 4.0cm^{-1} and 32 scans. To unravel the FT-IR peaks, the Guassian function was used and the ratio between the bands at 1047 cm^{-1}, 1022 cm^{-1} annd 995 cm^{-1} was performed by recording the absorbance height to characterize the molecular order [21].

X- ray diffractrograms

The X- ray analysis was performed on starch sample in powder form using X- ray diffractometer. The X- ray source used was a CuKα type radiation with a wavelength of λ = 1.54Å, with scanning range diffraction angle from 2ɵ from 5 to 30^0; speed: 1^0/ min equipped with a secondary graphite beam monochromator. Samples were stored at ambient conditions in order to equilibrate the water within the sample before analysis [22].

Result and Discussions

Chemical parameters

The moisture content of the extracted rice was 11.80% for red rice and 11.20% for white rice (Table 1). The starch moisture content was within the Indian standard as per IS 4706-2 (1978) which specifies a maximum value as 14% by mass. Moisture in broken grains of Sona Masuri rice also reported values in a similar range [23]. The presence of ash in red rice was 0.50 and white rice was 0.25%. It can be attributed to the fact that red rice is nutritionally more enriched than white rice flour [23]. The crude fat content of red rice was 0.51% and white rice was 0.34%. The low lipids content might be due to the fact that red rice starch has more fat due to retained lipids from the outer layers and more starch-lipid interaction whereas white rice has most of its fat-containing layers removed, so its starch contains less bound lipid [24]. Rice is a cereal of low protein content. Therefore, their starches also have low protein content of 0.32 in red rice and 0.46% in white rice. The reason can be high solubility of glutelin, globulin and albumin in NaOH [25].

The extraction yield of red rice was 65%, while white rice yielded 58%.

The extraction yield of red rice was 65%, while white rice yielded 58%. The extraction yield was reported as 67.84 % for red rice which was almost similar to our findings [27]. Likewise, in another study extracted yield of starch from red rice was 47.05%, followed by white rice having value as 44.05% and black rice as 37.74% [22]. Even though white rice is mostly starch, red rice yield has more extractable starch due to less processing, better granular integrity and favourable granular characteristics, especially in wet extraction processes. The data obtained in this study is closely aligned with existing literature having extraction yield of 49.11% in red rice [28].

The starch content in red rice was 82.50% and 86.33% for white rice. The red rice has lower starch content due to more non-starch components whereas white rice has higher values due to pure endosperm [29]. Similarly, other studies also recorded starch content of 86.54% for red rice [27].

The starch presented amylose content of in red rice 25.71 and 17.23 in white rice. The literature also reported amylose content around 15 to 26%. Bran in red rice can influence starch granule integrity and extraction, and potentially affects apparent amylose levels in extracted starch [22], [28].

Water absorption capacity is the ability of starch to absorb and hold water under specific conditions. The water absorption for red rice starch was 109 $g/100g^{-1}$ and for white rice was 81 $g/100g^{-1}$. The water absorption capacity (%) of the extracted starch is temperature-dependent as the water absorption capacity increases with an increase in solution temperature. It might be due to the increase in temperature, resulting gelatinization of starch and also reported water absorption capacity in the range of 75.33, 80.67, 105.00, 139.33 and 194.67% [26]. Other findings, also reported water absorption of black rice and red rice at 63.66 and 70.01 respectively [28].

In relation to oil absorption red rice showed higher absorption of oil at 76.60 whereas white rice had 56.60 $g/100g^{-1}$ of oil absorption, respectively. Similar results were obtained in the range of 86.90 in black rice and 78.90 in red rice [27]. The oil absorption of the six Nigerian rice cultivars was also measured at 112.55 to 150.19 $g/100g^{-1}$[30].

Fourier Transform Infrared Spectroscopy

There are bands in the region of 3292cm^{-1} in red rice and 3278cm^{-1} related to the stretching of O-H groups. Bands referring to the region of 2928 cm^{-1} and 2926 cm^{-1} involve C-H in red rice and white rice, respectively. Those at 1642 and 1643 cm^{-1} may be involved with water bound in starch [31]. It can be seen that a band with a region of 1149.38 for red rice and 1149.47 for white rice, it is related to the C-O-C glycosidic bond while 1076.68 of red rice and 1076.79 of white rice are related to C-O and C-C. Band patterns in the region between 1012.77 in red rice (Fig1)and 998.62 of white rice (Fig 2)are associated with the vibrational motion of H-O-H groups [32]. Minor differences in intensity were observed between red rice and white rice.

X-Ray Diffraction Analysis

The primary intensity peaks of crystallinity observed in the diffraction patterns correspond to 2θ angles of 15°, 17°, 18°,19° and 23^0 for red and 15^0, 17^0, 18^0,20^0 and 23^0 for white rice starch. Acute peaks clearly indicate the presence of the crystalline region, while diffuse peaks distinctly represent the amorphous region of the samples [33]. Minimal differences in intensity were detected between the diffractograms of red and white rice starch.

These distinctive peaks are typical of starch derived from cereals and are ascribed to V-amylose-phospholipid complexes [34]. The highest degree of crystallinity observed in the XRD analysis was 19° for red rice (Fig3) and 20.00° for white rice (Fig 4). This aligns with the literature, which indicates that the degree of crystallinity for starch typically ranges between 20% and 45%. The 2ɵ diffraction angles of black and red rice starch study also presented peaks at 15.33^0, 17.44^0, 18.48^0 and 23.45^0[27]. The results are also in accordance to the peaks observed in rice and other starches at 15^0, 17^0, 18^0, 20^0 and 23^0 where effect of single and dual heat moisture was studied [35]. The variation in crystallinity is due to the differences in the ratio of amylose to amylopectin [36].

Conclusion

Rice can be used as a raw material to extract starch. The extraction procedure of alkaline steeping was successfully implemented to obtain better starch yield. Variations can be observed in in chemical parameters of white rice starch and red rice starch. The red rice exhibited higher extraction yield than white rice starch. The water and oil absorption capacity was found to be higher in red rice than in white rice. The starch and amylose content was obtained higher in white rice than in red rice. Minor differences in infrared absorption spectra (FTIR) intensity were observed between red rice and white rice starch. Starches from red rice and white rice showed type A crystallinity. Therefore, both red and white rice can be utilized as sources of starch; but, because red rice contains more nutrients than white rice, it is a better option for functional food ingredients.

Future scope of the study

These findings provide a robust dataset to bridge knowledge gaps on red rice starch, offering insights for rice breeding programs and supporting the valorization of red rice in sustainable food systems. This work lays a foundation for optimizing starch-based applications and promoting dietary diversity through underutilized rice varieties.

Conflict of interest

No conflict of interest

Acknowledgement

We gratefully acknowledge the Division of Food Science and Technology of SKUAST- Jammu for providing the facilities and technical support for the analytical experiments. The services extended by the Central Instrumentation Facility (CIF), Lovely Professional University in the XRD and FTIR analysis is acknowledged.

Table 1: Chemical parameters of red and white rice starch

Parameters	Red Rice Starch	White rice starch
Moisture (%)	11.80	11.20
Ash (%)	0.50	0.25
Crude fat (%)	0.51	0.34
Crude protein (%)	0.32	0.46
Extraction yield (%)	65.00	58.00
Starch (%)	82.50	86.33
Amylose (%)	25.71	17.23
Water absorption (g/100g-1)	109.00	81.00
Oil absorption (g/100g-1)	76.60	56.60

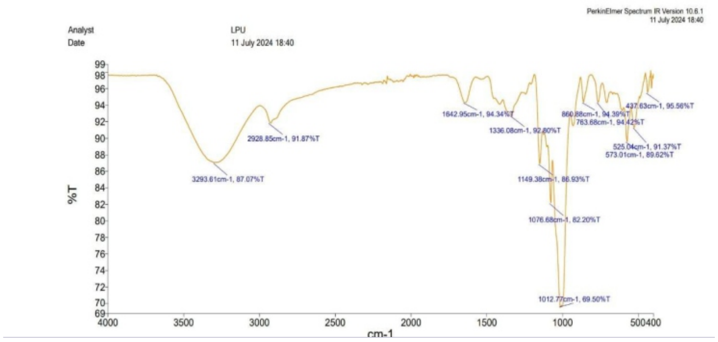

Fig-1 FTIR of red rice rice starch

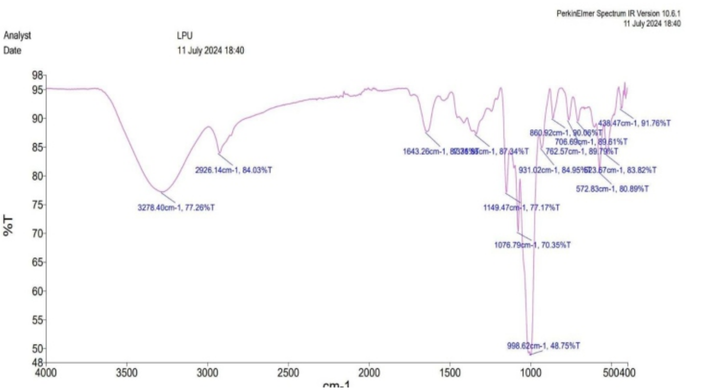

Fig - 2 FTIR spectrograms of white rice starch

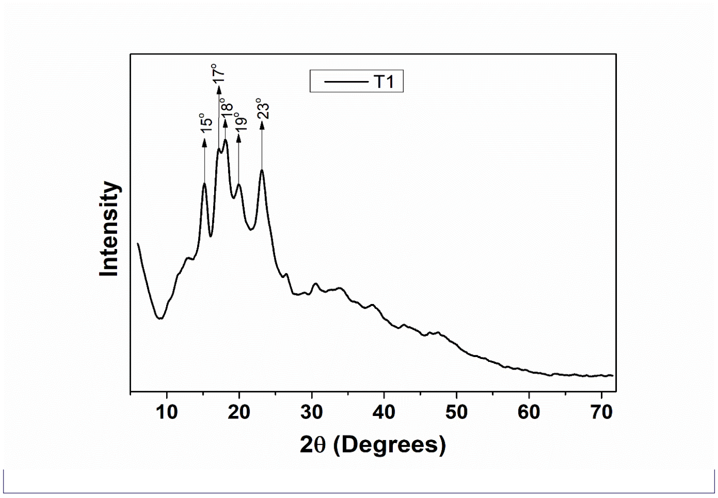

Fig - 3 X-Ray diffraction (XRD) of red rice starch

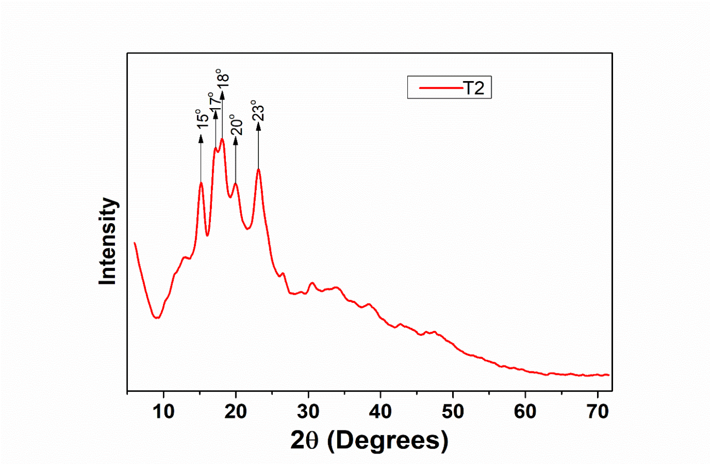

Fig-4 X- ray diffraction of white rice starch

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