Optical and Physical Properties of Rice and its By-Products: A Detailed Analysis

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Abstract: Our country has enough potential to produce rice and also in past cultivation of rice was linked with culture. In state of Chhattisgarh, rice production holds share of 6% of total rice production. Rice has different types and also different by-products i.e. Glutinous Rice, Puffed Rice and Flat Rice Grain. The rice and its by-product can be used for different useful purpose i.e. making of glue, packing material in food products, making of food products etc. In this study physical and optical characteristics by use of various experimental setups. The four types of rice and its by-products are taken as sample i.e. normal rice, puffed rice, flat rice and glutinous rice. After experiment its was observed that each of these samples have different properties based on their use.

Keywords: Rice, viscosity, optical, XRD, SEM, RVA.

1. Introduction

Our country had always an important centre for the production of rice. Total agricultural land being used for rice cultivation holds largest share in land use pattern for agricultural land. According to historians, it was believed that, Indica variety of rice first cultivated in India on foothills of the Eastern Himalayas (i.e. north-eastern India), expanding through near by South-East Asian countries while the japonica variety was arrived from woods of southern China. Assam and Nepal are the areas which still holds production of Perennial wild rice. After its introduction in northern Indian plain it was also spread over southern India to the alluvial geography, watered by rivers. Some of historians believes that word rice has been transformed from Tamil word arisi. The first written scriptures in which rice made its presence is Yajur-Veda (c. 1500-800 BC) and then is become often popular in various Sanskrit scriptures and texts. India after its independence, joys the appreciation of world in agriculture as production of food grain raised from 50.8 million tons (mt) in1950-51 to 316.06 mt in 2021-22 [1], and major share of this food grain production was of 127.93 MT of rice, 111.32 MT of wheat, 49.86 MT of coarse cereals, and 26.96 MT of pulses [2]. At present, even after extent of development in food grain, rice is still playing a role of key component for sustainable food production of India. In this total production of rice, Chhattisgarh State holds approximately 6% share of total rice production[3]. Thus, Chhattisgarh has potential to use rice for different

useful purpose according to it various physical and chemical properties. Rice has different types and also different by-products i.e. Glutonious Rice, Puffed Rice and Flat Rice Grain. These all different types and its by-products are having different physical and chemical characteristics. Rice is a staple meal, and its byproducts are also extremely well liked by the public. We have four samples for the current work: glutinous rice grain, normal rice grain, puffed rice grain, and flat rice grain. Aijung rice, which is readily available in stores, is the standard rice. We selected these grains since they are all descended from rice. Glutinous rice is a unique variety of rice that is created by using a unique process from regular rice. Because glutinous rice is so sticky, we decided to utilize a sample of it. Flat rice and Puffed rice are made from rice using specialized production techniques (By heating and applying pressure). Each of the four has a unique form, size, colour, and look. In this study, it is planned to compare optical and physical characteristics to understand how the characteristics of the specimens relate to one another. To understand the surface characteristics of several rice kinds and rice-derived products.

2. Literature review

Various studies have been conducted in the past to examine the surface property and its impact on light reflectance for various dietary grains. Additionally, research is being done on how liquid thin films affect light reflection. Gregory A. Carter has studied how water content affects spectral reflectance both directly and indirectly. Through his research, he discovered that the diffuse reflectance of leaves between the wavelengths of 400 and 2,500 nm is most significantly impacted by water's absorption of radiation [4]. There are other, less important fundamental consequences of scattering by water molecules. The secondary impacts of wave-optical processes are likewise insignificant in comparison to the significant impact of water absorption. The surface characteristics of barley straw have been examined by Sylwia K. Wisniewska and others (2002). Their research has shown the morphological and chemical complexity of the surface of the barley straw [5]. Different water contact angle values were noted for distinct straw components. The -diketones, alkanes, and esters were the primary components of the straw wax. Researchers, have researched how surface roughness affects how light is scattered by tiny particle spheres. Surface roughness has a minimal impact on light scattering for (Roughness parameter) 1. The mechanical characteristics of different rice grains have been studied. It was discovered that different kinds' characteristics varied. The qualitative attributes of puffed rice have been addressed by Corazon P. Villareal and Bienvenido O. Juliano et al [6]. Surface roughness and specular reflection at normal incidence have been examined by researchers. It was discovered that wavelength dependency may be obtained from reflectance at normal incidence to surface roughness. Some researchers, conducted research on the surface properties of

raw, solvent-extracted rice straw, as well as intact rice plant steam [7]. Using scanning electron microscopy, resaerchers investigated how rice starch is extracted and its shape [8]. Rice grain structure was demonstrated by researchers using SEM. Some, researchers have investigated the physical characteristics of rice under various meteorological situations [9]. Based on the Rapid Visco Analyzer pasting profile, Shafie, B., Cheng, S. C., Lee, H. H., and Yiu, P. H. et al categorised and described the rice grain [10]. Japanese rice was investigated using RVA measures by some researcher's [11]. Md. Rabiul Islam, Naoto Shimizu, and Toshinori Kimura evaluated the parboiled rice's quality using RVA [12]. A highly helpful tool for analysing the quality, rheology, and productivity of food products is the Rapid Visco Analyzer (RVA) [13]. Some foods get sticky for a variety of physical and chemical causes. This was researched by group of researchers and discovered numerous test procedures [14]. For different rice grains, it is also possible to compute the kind and degree of crystallinity [15] [16].

3. Methodology and materials

We have four samples for the current work: glutinous rice grain, normal rice grain, puffed rice grain, and flat rice grain. Aijung rice, which is readily available in stores, is the standard rice. The snapshot of samples are presented in Figure 1.

Type of Rice / Byproduct	Photo of Sample	Type of Rice / Byproduct	Photo of Sample
Normal Rice		Puffed Rice	
Flat rice		Glutinous Rice	

Figure 1: Photograph of Samples

We selected these grains since they are all descended from rice. Glutinous rice is a unique variety of rice that is created by using a unique process from regular rice. Because glutinous rice is so sticky, we decided to utilize a sample of it. Flat rice and Puffed rice are made from rice using specialized production techniques (By heating and applying pressure). Each of the four has a unique form, size, colour, and look.

3.1 Physical properties of samples taken:

Physical properties are those properties which can be determine without any chemical or instrumental process. The

physical properties of our rice and byproducts are detailed in Table 1.

Table 1: Physical properties of above samples

Properties	Glutinous Rice	Normal Rice	Flat rice	Puffed rice
Size and Shape	Long grained (Oval Shaped)	Long grained (Cylindrical orOval)	Flat light dryflakes.	Long grained(Oval shaped)
Colour	White	White, Black,Brown or Red.	In generalBrown.	In general,White and Brown.
Manufacturing Process	Once seeds have been extracted from plants, they are dried, and various machinery are used to remove the outer layer (cover surrounding the seeds).	After obtaining seeds from plants, the outer layer (the covering around the seeds) is removed using a variety of devices.	After being cooked and pressed into thin, dry flakes, regular rice is prepared. Additionally, a variety of culinary items are added to improve the flavour.	Rice kernels are heated while being subjected to high pressure and steam. Additionally, a variety of culinary items are added to improve the flavour.
Mass (per grain) in gm	0.0178	0.0169	0.0141	0.0161
Density in gm/cm^3	0.81	0.75	0.28	0.089
Calories (per 100gm)	95	135	249	398
Length in cm	7	7	12	12
Dryness	Medium	High	Very High	Very High

In this study, it is planned to compare optical and physical characteristics to understand how the characteristics of the specimens relate to one another. We employed the following experimental techniques to examine our samples:

3.2 UV-Visible spectroscopy

Incoming light can cause an atom to respond. Light can either be absorbed or scattered by it. Light may be diverted or have its direction changed during dispersion. When light is absorbed, the atom often makes a quantum leap to one of its higher energy levels. The characteristic of a substance that determines how much light is absorbed by it is called the absorption coefficient. The average distance a photon travels before it is absorbed is the inverse of the absorption coefficient. Its working phenomenon is presented in figure 2.

The formula of absorbance is here as

$$A = \alpha cl$$

Where, α – Absorption coefficient,

c – concentration,

l – path length

The transmittance is defined as the ratio of incident light intensity to transmitted light

intensity (I/I0) (T). Absorbance (A) and transmittance (T) are connected with this formula

$$A = -\log T = \log (1/T).$$

Absorbance and absorbance coefficient are computed can be computed through a spectrophotometer. According to Tauc's formula

$$\alpha h\nu = A(h\nu - E_g)^n$$

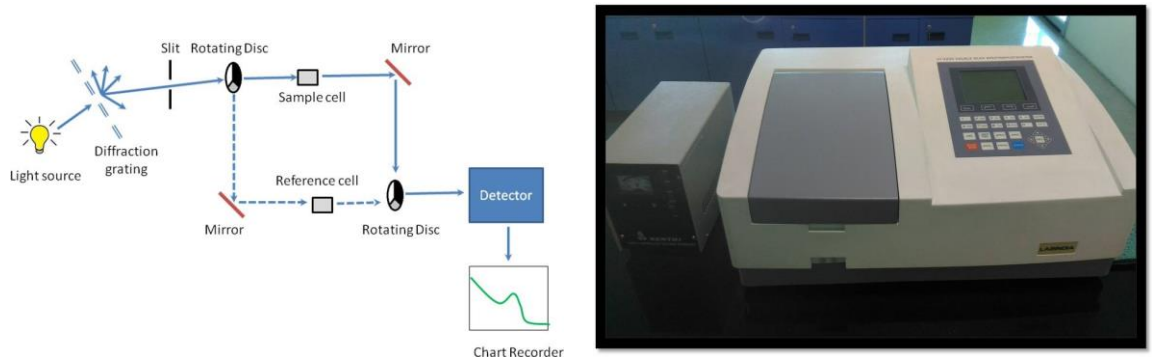


Figure 2: Schematic diagram of UV-Visible Spectrophotometer working and an UV spectrophotometer

Where,

Eg = Band gap energy of the semiconductor,

E = Energy of the incident light, then we have

n depends on nature of transition and can have values 1/2(allowed) and 3/2(forbidden) for direct transition; 2(allowed) and 3(forbidden) for indirect transition.

3.3 Scanning electron microscopy (SEM)

This instrument is very powerful microscope and enables to creates a picture of things using electrons as opposed to light. It is sizable and enables the creation of three-dimensional things. The De Broglie theory states that electrons exhibit both a particle and a wave character. As a result, diffraction phenomena also occur in electrons. Again, atoms scatter electrons considerably more effectively than x-rays do. This is owing to the entirely elastic nature of electron scattering caused by the atom's electrons. However, the penetration depth for elastic scattering for an electron with an energy of 50 keV is only approximately 50 for the short angle of incidence utilised in reflection methods. The atoms on the surface of a substance release electrons when an electron beam strikes it. We refer to them as secondary electrons. Backscattered electrons are incident electrons that are elastically scattered. Once more, incident electrons knock some electrons from the inner shell to the outer shell. An electron beam is created in a SEM by an electron cannon on top of the microscope. Through EM fields and lenses, the electron beam travels vertically before being focused on the sample. The setup is maintained in a vacuum. Electrons are emitted from the

material's surface when the beam strikes it. The electrons relayed to displayed are gathered by the detector, transformed into a signal. Schematic diagram of SEM working has been presented in figure 3.

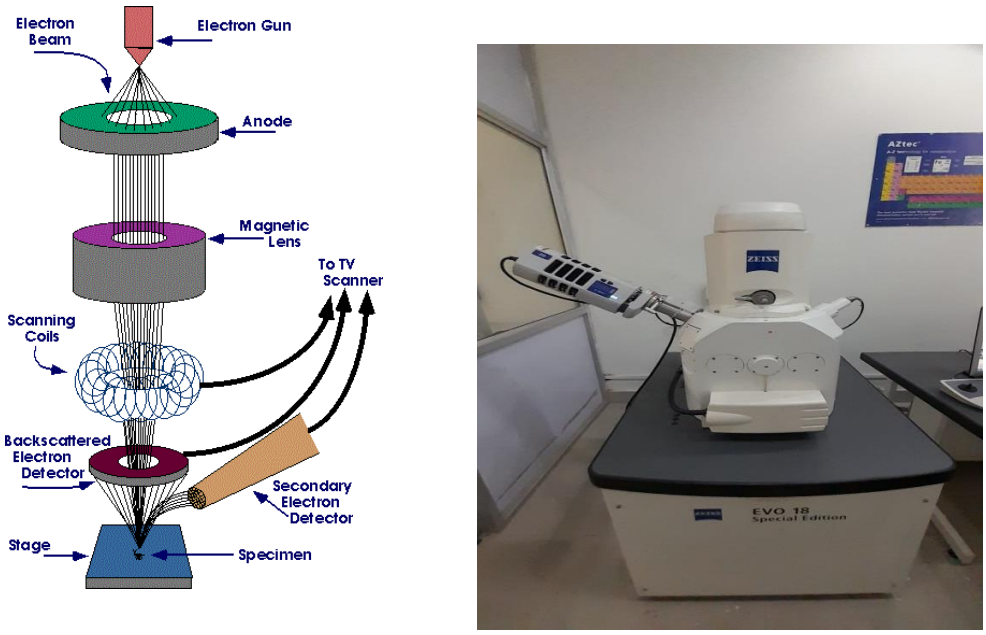


Figure 3: Schematic diagram of SEM working and its photograph

3.4 X-Ray diffraction study (XRD)

A powerful method for examining a material's structural characteristics is X-ray diffraction. A schematic diagram of XRD and its photograph is presented in figure 4. Similar to how visible light waves are diffracted by a diffraction grating, the incident X-rays scatter in several atomic planes of the material that have Miller Indices (h, k, and l). The reflected X-ray from these planes generates interference. So it also goes by the name "X-ray diffraction." For X-ray diffraction, Bragg provided a highly helpful law known as Bragg's law, which is

$$2d_{hkl}\sin\theta = n\lambda \ldots\ldots \quad (1)$$

Where,

n = 0, 1, 2, 3... is the order of the diffraction, '

d_{hkl} = interplanner distance;

θ = angle of incidence

λ = wavelength of the incident X-ray.

The figure of the X-ray diffractometer is given below –

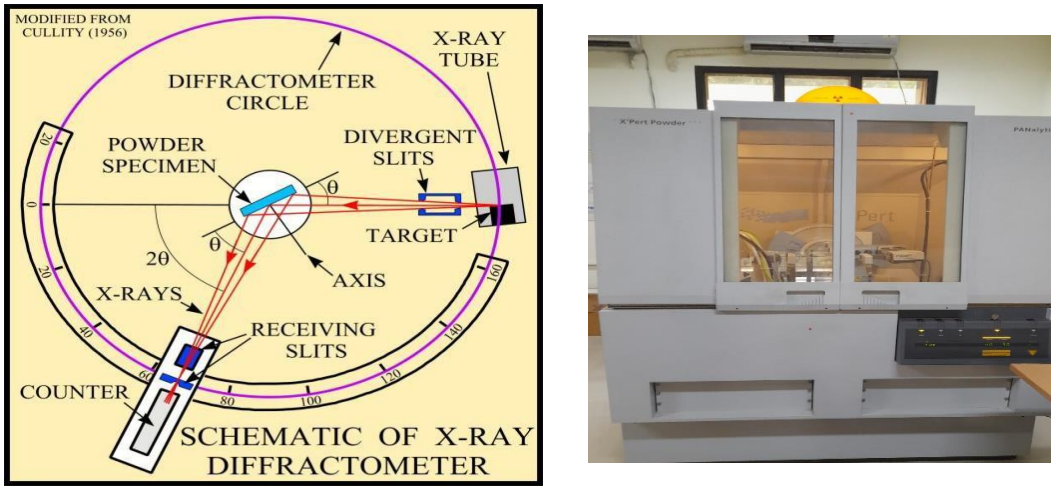


Figure 4: Schematic Diagram of X-ray Diffractometer and its photograph

Numerous structural characteristics of the solid may be obtained via the XRD examination. They are –

Inter-planner Spacing ‘d’

Grain Size or Crystallite Size ‘D’

Crystallinity

3.5 Rapid visco analyzer (RVA)

When starch is cooked in excessive amounts of water, the vast majority of food items have different pasting characteristics (properties linked to viscosity and shear rate). These characteristics provide us a good understanding of the food product's quality, behaviour, and development.

A special instrument for product development, quality and process control, and quality assurance is the Rapid Visco Analyzer. The RVA is a cooking and stirring viscometer with ramping temperature and varied shear capacity, making it ideal for evaluating the viscosity of foods like starch, grain, and flour. With the use of custom-made test routines for mixing, measuring, heating, and chilling, the equipment can analyse samples as little as two or three grammes using procedures that are considered to be worldwide standards. The photograph of RVA is presented in figure 5.

The parameters which can be calculated from RVA are-

1. Peak Viscosity
2. Hold Viscosity
3. Final Viscosity
4. Breakdown Viscosity
5. Stability Ratio
6. Setback Viscosity
7. Total Setback
8. Ratio of Setback
9. Pasting Temperature

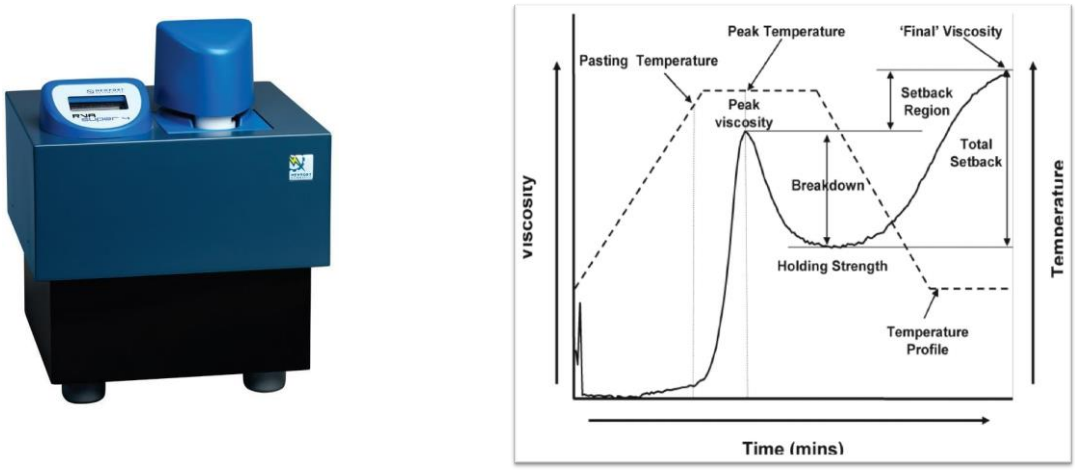
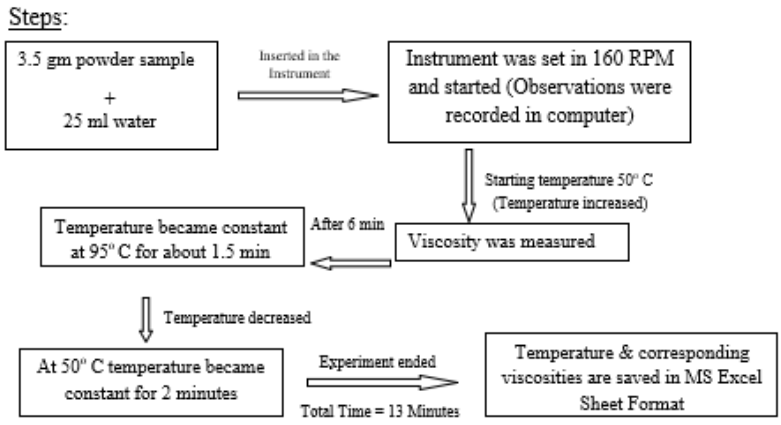


Figure 5: Rapid Visco Analyzer Experimental Setup and RVA Profile

RVA experimental procedure:



These processes were repeated for all the four samples.

3.6 Porosity Calculation

Formula of Porosity is given here as-

$P(\%) = (V_i - V_f)/V_s \times 100\ \%$

Where, P = Porosity of the sample (%)

V_i = The combined volume of the sample + added water (mL)

V_f = The final volume of the sample + added water (mL)

V_s = The volume of the sample (mL)

.

4. Result and analysis

4.1 Crystallinity measurement from XRD plot

All of the rice samples studied using X-ray diffraction displayed a remarkably uniform pattern, except in the case of glutinous rice, there are some early variations

Table 2: Crystallinity of sample

Type of Sample	Percentage of Crystallinity,t
Glutinous Rice	16.14%
Normal Rice	26.01%
Puffed Rice	23.88%
Flat Rice	17.01%

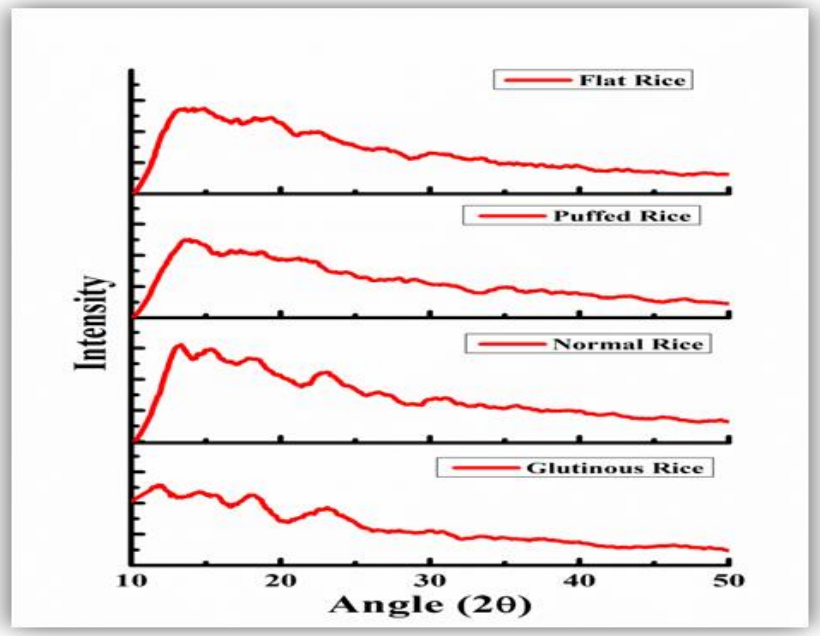


Figure 6: Patterns of X-ray diffraction

Peaks are seen for glutinous rice at 23.1° and 15.18°, demonstrating a C-type pattern. Additionally, C type patterns are seen for normal rice (peaks at 18.1o and 23.1o). Puffed rice and flat rice, on the other hand, don't exhibit any distinctive patterns since their peaks don't match the value predicted by theory. Therefore, the crystallinity of rice grains is influenced by the production process [16-21]. The percentage of crystallinity is given in table 3.

As a result, we discovered from the crystallinity values that glutinous rice had lower crystallinity than normal rice. Rice byproducts exhibit less crystallinity than regular rice. Because none of the samples had more than 30% crystallinity, we may conclude that rice and its byproducts are primarily amorphous.

4.2 Observation of optical properties using UV-Vis spectroscopy:

Observations of UV-Vis Reflectance Plot:

1. For all four samples, the reflectance curve exhibits the same pattern.
2. Glutinous rice has the strongest light reflection.
3. Puffed rice has a somewhat distinct set of traits.
4. For glutinous rice, peaks are seen at 310 and 400 nanometers.
5. Puffed rice and flat rice exhibit about similar reflectance, as may be observed.
6. Normal rice, puffed rice, and flat rice all show no peak. For these three kinds, a gradual ascent without a clear apex is seen.

7. Puffed rice has lower reflectivity than flat rice size below 540 nm, but puffed rice exhibits greater reflectance above 540 nm.

Figure 7 displays the reflectivity bands for each of the four samples. -

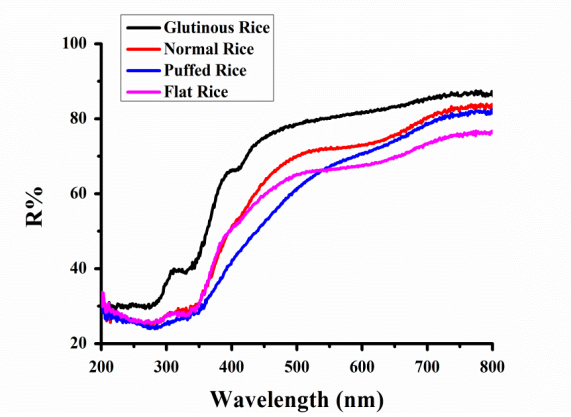


Figure 7: reflectivity bands of all the rice grains

4.3 Microstructure analysis through SEM:

Normal Rice

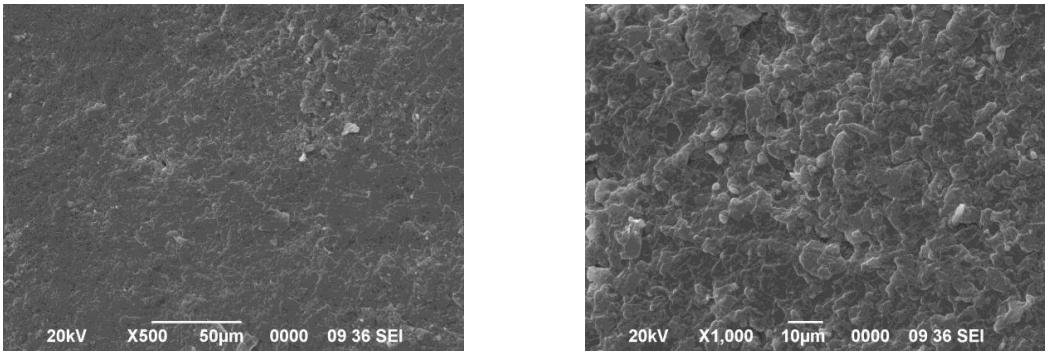


Figure 81: Image of SEM Test on Normal Rice at different magnifications

Flat Rice

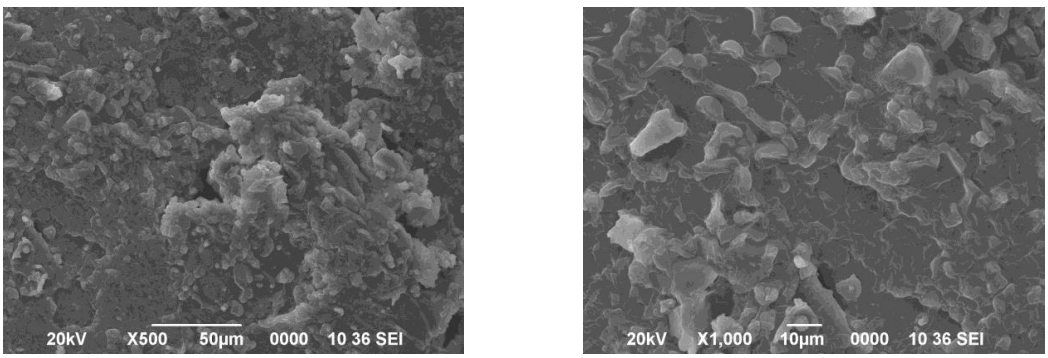
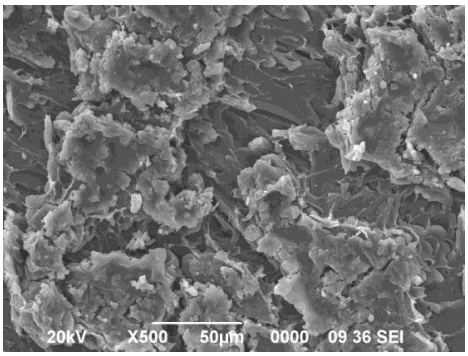


Figure 9: Image of SEM Test on Flat Rice at different magnifications

Puffed Rice



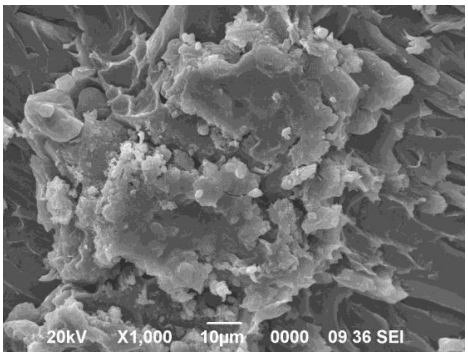


Figure 10: Image of SEM Test on Puffed Rice at different magnifications

Comparison of SEM images of three sample

Table 3: Comparison of samples

Sl. No.	Normal Rice	Flat Rice	Puffed Rice
1	Full of starch	Full of starch.	Full of starch.
2	Void fraction not by considerable measure.	Although the void percentage is significant, it is not as high as it would be for puffed rice because of the pressure used during manufacture.	As cellular materials expand as a result of the applied heat during the production process, the void percentage is quite large.
3	Holes are not usually visible on the surface.	Holes are not usually visible on the surface.	There are visible holes on the surface due to applying heat is the reason of this.
4	In this rice reflectance is high because its roughness is low.	In this rice reflectance is low because its roughness is high.	In this rice reflectance is low because its roughness is high.
5	Granules are less visible and vary in size and structure.	Granules of starch come in a variety of sizes and shapes.	Granules of starch vary in size and structure.
6	Granules have a tiny size, on the order of 1 µm.	Granules have a small size , on the order of 1-10 µm.	Granules have a more large size than normal and flat rice, on the order of 1-10 µm.. Due to the expansion of cellular material dimension increases.

4.4 Porosity

We have observed that glutinous rice has a higher ability to absorb water than regular rice because of its naturally sticky character [22]. The porosity of flat rice and puffed rice cannot be tested since their surfaces are instantaneously destroyed when water is introduced.

4.5 Rapid Visco Analyzer (RVA)

Instrument Used for Observation of Viscous & Pasting Properties

The RVA profile, which provides us all the sample's pasting characteristics, is a plot between the sample's temperature, time, and viscosity during the experiment. Analyzing a food

material's quality, behaviour, and other attributes is quite helpful.

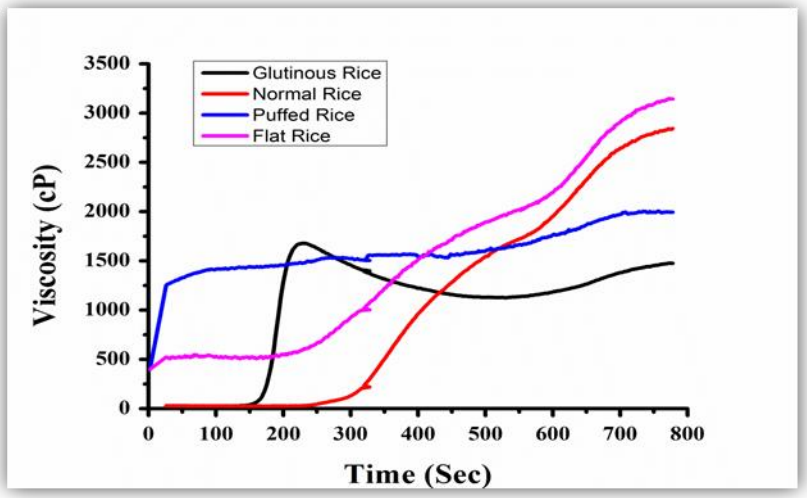


Figure 11: Curve for all the samples between Viscosity vs Time

Results of experiment using Rapid Visco Analyzer (RVA):

With use of Rapid Visco Analyzer (RVA), we get following information, which is shown in following table

Table 4: Rapid Visco Analyzer (RVA) information

Type of Rice	Pasting Temperature (degree C)	Peak Viscosity(cP)	Hold Viscosity(cP)	Breakdown Viscosity (cP)	Total Setback Viscosity (cP)	Final Viscosity (cP)
Glutinous Rice	63.5	1657	1101	547	348	1466
Normal Rice	78.9	1159	-	-	1468	2833
Puffed Rice	47.9	-	-	-	2863	1986
Flat Rice	47.4	-	-	-	1989	3141

*Where, unit of viscosity is centipoise (cP)

5. Conclusion

In this study, we have studied optical, morphological, and physical behaviors of samples of glutinous rice grain, normal rice, flat rice, and puffed rice. We have discovered the moderately porous, helix, 6 folds, crystalline structure of rice using XRD peaks (C type peaks). We noticed that the glutinous rice had the maximum reflectivity from the reflectance spectrum. In addition, the surface structures of the four samples vary in terms of their degree of roughness. The primary element affecting how

light reflects changes in surface structure. Using RVA data, we can see that various samples have varied pasting properties. We were able to choose the best rice cultivars thanks to the categorization of cultivars based on RVA profiles. When compared to other grains of rice, glutinous rice is extremely sticky, according to RVA data and shear rate measurements. It can also be assessed using a porosity measurement. High stickiness results from high porosity.

6. Acknowledgement

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7. References

[1]. Ministry of Agriculture & Farmers Welfare, Government of India

[2]. pib.gov.in

[3]. Statistical Year Book India 2018, Ministry of Statistics and Programme Implementation

[4]. Gregory A. Carter, "Primary and Secondary Effects of Water Content on the Spectral Reflectance of Leaves", American Journal of Botany; Vol. 78(7), **(1991)**, 916-924.

[5]. Sylwia K. Wisniewska, Jakub Nalaskowski, Edyta Witka-Jezlewska, Jan Hupka, Jan D. Miller; "Surface properties of barley straw; Colloids and Surfaces B:, Biointerfaces; Vol. 29, **(2003)**, 131-142.

[6]. Corazon P. Villareal and Bienvenido O. Juliano; "Varietal Differences in Quality Characteristics of Puffed Rices" Cereal Chem. 64(4), **(1987)**, 337-342.

[7]. Maria K. Inglesby, Gregory M. Gray, Delilah F. Wood, Kay S. Gregorski,

[8]. Rachel G. Robertson, Glen P. Sabellano, "Surface characterization of untreated and solvent- extracted rice straw" Colloids and Surfaces B: Bio interfaces, Vol. 43, **(2005)**, 83–94.

[9]. D. Kodandaram Reddy and M.G. Bhotmange, "Isolation of Starch from Rice (Oryza Sativa) and its Morphological Study using Scanning Electron Microscopy", ISSN 2249-3050, Vol. 4, Number 9 **(2013)**

[10]. Yaning Zhang, A.E. Ghaly and Bingxi Li, "Physical Properties of Rice residues as affected by Variety and Climatic and Cultivation Conditions in Three Continents", American Journal of Applied Sciences; 9 (11), **(2012)**, 1757-1768.

[11]. Thakur, A; Dubey, A; Chandrakar, P; Verma; A. (2023 May). Analyzing Surfaces and Interfaces using Photoluminescence. European Chemical Bulletin, 12 (Special Issue 3), 3467 – 3474.

[12]. Shafie, B., Cheng, S. C., Lee, H. H. and Yiu, P. H., "Characterization and classification of whole-grain rice based on rapid visco analyzer (RVA) pasting profile", International Food Research Journal 23(5), **(2016)**, 2138-2143.

[13]. Sandya ,P., Verma, A. (2023 April). Optical and Physical Properties of

Rice and its By Products: A Detailed Analysis. Journal of University of Shanghai for Science and Technology. 25(4), 133-146.

[14]. Amit Kesarwani, Po Yuan Chiang and Shih Shiung Chen, "Rapid Visco Analyzer Measurements of japonica Rice Cultivars to Study Interrelationship between Pasting Properties and Farming System" International Journal of Agronomy; Article ID 3595326, **(2016)**, 6 pages.

[15]. Verma, A. (2023). Review of Nanomaterials' Current Function in Pollution Control. Recent Trends of Innovations in Chemical and Biological, 5, 34.

[16]. Md. Rabiul Islam, Naoto Shimizu and Toshinori Kimura, "Quality Evaluation of Parboiled Rice with Physical Properties", Food Science and Technology Research; 7(1), **(2001)**, 57- 63.

[17]. http://www.perten.com/Publications/Articles/Applications-of-the-Rapid-Visco-Analyser-RVA-in-the-Food-Industry-a-broader-view/

[18]. B. Adhikari, T. Howes, B. R. Bhandari and V. Truong, "Stickiness in Foods: A Review of Mechanisms and Test Methods" International Journal of Food Properties, 4(1), **(2001)**, 1–33.

[19]. Verma, A. (2023, February 03). CVD Graphene-1: Hybrid Nanostructures for PVC Applications. LAMBERT Academic Publishing. ISBN: 978-620-6-14310-9.

[20]. Hyun-Jung Chung, Qiang Liu, Laurence Lee, Dongzhi Wei, "Relationship between the structure, physicochemical properties and in vitro digestibility of rice starches with different amylose contents", Food Hydrocolloids, 25, **(2011)**, 968-975.

[21]. M. H. Ong and J. M. V. Blanshard, "Texture determinants in cooked, parboiled rice. I: Rice starch amylose and the fine structure of amylopectin" Journal of Cereal Science 21, **(1995)**, 251–260.

[22]. Sinha, I., Verma, A., Shrivastava, A. (2023 May). Synthesis of Polymer Nanocomposites Based on Nano Alumina: Recent Development. European Chemical Bulletin, 12 (Special Issue 4), 7905-7913.