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Facile Synthesis, Properties of Rice Starch and Its Applications

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Abstract: Starch is a widely used natural polymer in both food and non-food industries due to its excellent stabilizing and binding properties. There is a surplus demand for starchy foods because they have been consumed for a long time. Starch is used in the food industry as a thickener, stabilizer, texture modifier, gelling agent, fat substitute, and shelf-life extender. In applications other than food, it functions as an absorbent, sizing agent, binder, adhesive, and disintegrant. It is also used to strengthen the binding between materials. Rice starch stands out for its fine granule size, neutral taste, hypoallergenic nature, and better digestibility, making it suitable for specialized uses. This study presents a simple method for extracting rice starch and characterizes it using traditional methods and viscometry. The work also highlights the chemical and physical properties of rice starch and its potential applications across various industries.
Keywords: Rice starch - Alkaline Extraction Method – Starch Properties – Amylose and Amylopectin – Viscometry – Gelatinization – Kjeldahl Method – Soxhlet Extraction – Acid Hydrolysis – Hypoallergenic Starch – Applications.

I. INTRODUCTION

Starch is the primary carbohydrate found in rice (*Oryza sativa* L.), one of the most widely consumed staple grains in the world, especially in Asia. It comprises approximately 70–80% branched amylopectin and 20–30% linear amylose, making rice starch highly functional and adaptable for various industrial applications. In the food industry, rice starch is extensively used as a thickening, gelling, and bulking agent due to its unique structural and physicochemical properties[1]. According to recent studies, the versatility of rice starch has extended its usage beyond food, into non-food sectors such as pharmaceuticals, textiles, cosmetics, and paper manufacturing. India is among the largest rice-producing countries, with an annual output of 1357.55 lakh tonnes, positioning rice as the second most important cereal crop after maize and corn. Industrial applications of rice starch continue to expand, especially in the production of baked goods, syrups, protein isolates, and rice hydrolyzates[2]. Approximately 80% of freshly harvested rice grains consist of carbohydrates, including glucose, dextrin's, sucrose, and starch. Structurally, starch is an insoluble carbohydrate formed by α-glucose polymers connected through α-1,4 and α-1,6 glycosidic linkages[3]. Amylose and amylopectin, the two primary components of starch, significantly influence its functional behaviour, particularly during gelatinization and retrogradation processes[4].

Rice grains consist of three major components: the hull, the bran layer, and the starchy endosperm. In the context of rice starch extraction, broken rice is preferred due to economic viability[5]. Unlike maize starch, rice starch generally exhibits a smoother, creamier texture, neutral flavor, and enhanced stability under various cooking conditions. These attributes contribute to its increasing demand in gluten-free and allergen-sensitive formulations[6]. Rice starch also offers processing advantages—unlike cornstarch, which requires pre-slurrying with cold water, rice starch can be added directly to hot liquids. Its superior syneresis control and freeze-thaw stability make it suitable for applications like baby food, desserts, sauces, and long-cooked meals. Additionally, rice starch is naturally gluten-free, hypoallergenic, and characterized by a small granule size, white color, and bland flavor—qualities that make it highly suitable for health-conscious and special dietary needs[7]. Recent research indicates that rice starch possesses a wide range of amylose-to-amylopectin ratios, which are influenced by the biological and genetic makeup of the rice variety. These ratios affect the starch's digestibility, processing behavior, and organoleptic properties. Rice starch is also known to exhibit favorable responses to pressure-induced gelatinization and maintains structural integrity even under high heat and extended cooking durations[8].

Furthermore, studies have shown that rice starch generally forms weaker protein-fat bonds compared to corn or maize; however, these do not negatively affect its texture, digestibility, or functional performance during cooking and processing. The swelling behavior of starch granules, along with the release of soluble components, plays a critical role in defining the viscosity and pasting properties of starch during heating[9].

Retrogradation, the re- association of gelatinized starch molecules, is a phenomenon observed in both amylose and amylopectin, with amylopectin being more responsible for long-term changes in food quality and stability. In light of these functional benefits, rice starch has become a valuable raw material across multiple industries. Its growing demand in both food and non-food applications underscores the importance of studying its composition and functional properties[10]. The present study focuses on the extraction, characterization, and evaluation of rice starch in terms of its purity, moisture, protein, fat, fiber, ash content, and total starch percentage, using standardized analytical techniques. The results aim to highlight the potential of rice starch as a sustainable, versatile, and high- performance ingredient for various industrial applications.

II. PREPARATION OF RICE STARCH

Currently, rice starch is commercially isolated using either mechanical or traditional (alkaline) methods. While the mechanical method involves wet milling to release starch, the traditional method relies on alkali-based solubilization of rice grains. Historically, rice starch has demonstrated superior functional properties compared to other starches due to its unique structural characteristics[11]. In our study, we used the alkaline extraction method as the principal technique for isolating rice starch. We soaked rice grains in a 0.4% sodium hydroxide (NaOH) solution for 10 hours at 30°C to soften the endosperms. After the steeping process, we drained the NaOH solution and transferred the soaked rice to a separator, where we effectively separated proteins and fine fiber. Following separation, we rinsed the starch slurry using a decanter to enhance its whiteness. We then filtered the slurry through fine nylon cloth to remove residual impurities. To eliminate any remaining alkali, we washed the starch thoroughly and subsequently collected it via centrifugation. We then dried the isolated starch in a hot air oven at 40°C for 12 hour[12],[13]. This method enabled us to obtain high-quality starch with minimal alkali residues. We observed that different rice varieties exhibit significant variation in protein content, which is further influenced by the purification steps and overall starch quality[14]. A detailed flow diagram illustrating our alkaline extraction process is shown in Figure 1.

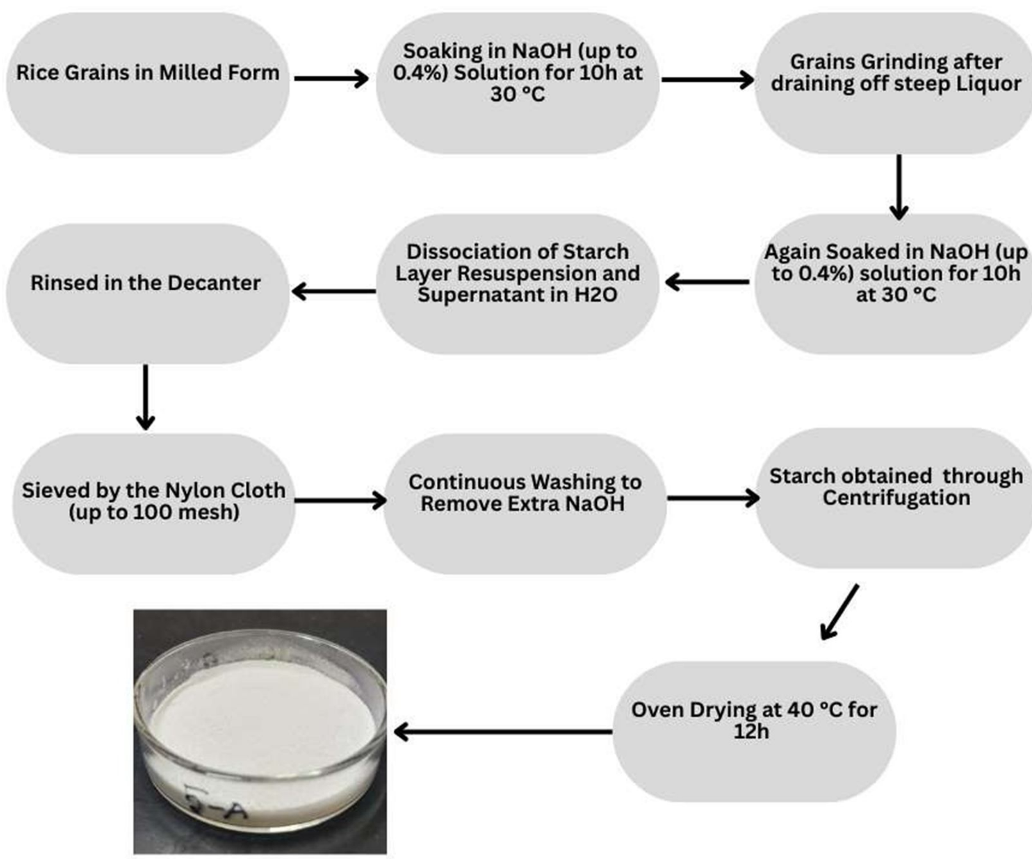

Fig.1. Preparation of Rice Starch by Alkaline – Based Method.

III. RESULTS AND DISCUSSION

We improved the quality and purity of rice starch by applying this extraction technique. We then analyzed the extracted starch for purity, moisture, protein, fat, fiber, and ash content in accordance with standard AOAC protocols, incorporating minor modifications where necessary[15].

A. Indicating the Total Contents of Starch

We employed the acid hydrolysis method to determine the total starch content in our synthesized rice starch sample. This technique involves the hydrolysis of starch into its monosaccharide components, primarily glucose, using a strong acid under controlled heating. The resulting sugar concentration is then used to calculate the original starch content. We began by pouring 200 ml of distilled water into a 500 ml flat-bottom flask and adding a known quantity of rice starch to it. We gently swirled the flask to ensure the starch dispersed evenly in the water. Next, we added 20 ml of 33% concentrated hydrochloric acid (HCl) to the mixture and heated the flask under reflux for two hours using a heating mantle. We continuously shook the flask as it heated to ensure thorough mixing and consistent hydrolysis. After completing the hydrolysis, we removed the flask from heat and allowed it to cool for 30 minutes. Once cooled, we neutralized the acidic solution by slowly adding 20% sodium bicarbonate solution, ensuring complete neutralization. We then filtered the hydrolyzed solution and collected the filtrate in a 250 ml volumetric flask. To quantify the released sugars, we performed titration using the Lane-Eynon method with Fehling's solution, which allowed us to determine the reducing sugar content. Finally, we calculated the total starch content of the sample based on the measured sugar concentration. Using this acid hydrolysis method, we determined that our synthesized rice starch sample contains approximately 99.03% total starch.

B. Total Moisture Content

To determine the moisture content of our synthesized rice starch sample, we used the gravimetric method by measuring the sample's weight loss after drying. We first cleaned a crucible and its lid thoroughly, then dried them in a hot air oven at 105°C for 30 minutes. After drying, we transferred them to a desiccator to cool to room temperature. Once cooled, we weighed the empty crucible with its lid and recorded the value. Next, we weighed 5 grams of the starch sample and placed it evenly across the surface of the crucible. We then placed the crucible in the oven and dried the sample at a temperature range of 105°C to 110°C for 4 hours. After drying, we transferred the crucible back to the desiccator, keeping the lid slightly open to allow cooling while avoiding moisture absorption. Once cooled, we weighed the crucible containing the dried sample and recorded the final weight. Using the weight difference before and after drying, we calculated that the moisture content of the starch sample was 10.31%.

C. Protein Content

We determined the protein content in our synthesized rice starch sample using the traditional Kjeldahl method, which estimates nitrogen content and subsequently calculates the protein percentage. We precisely weighed approximately 5 grams of the starch sample and transferred it into an 800 ml Kjeldahl digestion flask. To this, we added 1 gram of copper sulfate (as a catalyst) and 10 grams of sodium sulfate (to raise the boiling point). We then poured in 30 ml of concentrated sulfuric acid. Next, we placed the flask at an incline and gently heated it until the initial foaming subsided. We then increased the heat and continued heating until the solution turned a clear green color, indicating complete digestion. After digestion, we allowed the flask to cool to room temperature. We then added 250 ml of distilled water slowly, while gently swirling the contents. After this, we assembled the distillation apparatus, placing the lower end of the condenser so it just touched the bottom of a 500 ml conical flask containing 30 ml of boric acid solution and 3–5 drops of mixed indicator. We ensured the condenser's delivery tube was fully submerged in the boric acid solution. Then, we slowly added 30% sodium hydroxide solution through a dropping funnel along the side of the digestion flask to make the solution strongly alkaline. We ensured the dropping funnel remained filled during the addition. As ammonia formed, it distilled into the boric acid solution. We heated the mixture and allowed distillation to continue for about 20 to 30 minutes, collecting sufficient volume of distillate. After distillation, we removed the receiving flask and turned off the heat. Finally, we titrated the boric acid- ammonia complex with 0.1 N sulfuric acid (H_2SO_4) until the solution's color shifted from green to pale pink[16],[17]. Using this method, we calculated that the protein content in our synthesized rice starch sample was 0.41%.

D. Fat Content

We used the Soxhlet extraction method to determine the crude fat content in our synthesized rice starch sample. This method involves the continuous extraction of fat from the sample using a non-polar solvent. We accurately weighed 5 grams of the starch sample and transferred it into a 250 ml flat-bottom flask connected to a Soxhlet extractor. We then used petroleum ether as the solvent for fat extraction. Using Indian filter paper as the thimble, we ran the extraction process for 4 hours, maintaining a condensation rate of 5 to 6 drops per second. After completing the extraction, we removed moisture from the extracted oil by first placing the flask on a steam bath for 5 minutes. Then, we dried it in a hot air oven at 130°C for two hours to ensure complete removal of any residual solvent. Finally, we weighed the flask containing the extracted fat and compared it with the initial weight of the empty flask. This allowed us to determine the crude fat content in the sample. Using this procedure, we calculated that the fat content in our synthesized rice starch sample was 0.032%.

E. Ash Content

We used the standard gravimetric method to determine the ash content in our synthesized rice starch sample. Ash content refers to the amount of inorganic residue left behind after the complete combustion of organic matter in a sample. First, we heated and cooled a clean platinum (or silica) crucible and then weighed it accurately. We then weighed 5 grams of the starch sample and transferred it into the crucible. To initiate carbonization, we gently heated the crucible on a hot plate until the sample was thoroughly charred. During the charring process, we ignited the sample to accelerate the breakdown of organic materials. Next, we placed the crucible in a muffle furnace pre- set to 650°C and heated it for 2 hours, ensuring that the sample was completely burned and the resulting ash was free of carbon. After heating, we removed the crucible, cooled it in a desiccator, and then weighed it again to determine the final ash content. Using this method, we calculated that the ash content in our synthesized rice starch sample was 0.27%.

F. Fiber Content

We employed the Soxhlet extraction method to determine the crude fiber content in our synthesized rice starch sample. First, we accurately weighed 3 grams of starch and placed it into the Soxhlet extractor to extract with petroleum ether. After completing the extraction, we air-dried the sample and then transferred it into a 1000 ml conical flask. Next, we boiled the dried extracts in a solvent mixture of petroleum benzene and acetone for 30 minutes. We connected the flask to a water-cooled reflux condenser and heated it until the mixture started to boil within one minute. We ensured continuous spinning of the flask throughout the boiling period to maintain uniform heating. After boiling, we filtered the contents through fine linen placed in a funnel. We then washed the remaining residue with 200 ml of boiling sodium hydroxide (NaOH) solution. We immediately transferred the filtrate into another flask, connected it to a reflux condenser, and heated it again for 30 minutes. Following this, we filtered the contents again through filtering cloth and washed the residue thoroughly using 15 ml of ethyl alcohol and hot water. We then transferred the clean residue into a Gooch crucible and placed it in an oven at 105°C, drying it until it reached a constant weight. Once dried, we allowed the crucible to cool, then placed it in a muffle furnace to burn off the carbonaceous content until the material turned completely blackened. After cooling, we weighed the residue to calculate the crude fiber content. Based on our analysis, we determined that the fiber content in our synthesized rice starch sample was 0.21%.

G. Viscosity Analysis

Starch is continuously heated in excess water with stirring, the granules are swollen and ruptured due to the disruption of the native starch structure. As a result, amylose is leached out and the granules are disintegrated, leading to the formation of a viscous substance known as starch paste. The process of pasting is either initiated after or occurs simultaneously with gelatinization. The pasting properties of starch are considered crucial for evaluating its behavior during processing[18]. Starch is generally regarded as the most influential component of rice in determining cooking quality and functional performance. These properties are frequently used for assessing the suitability of starch in a variety of food products and other industrial applications. Among these properties, viscosity is identified as the most significant characteristic of granular starch dispersions. High paste viscosity is interpreted as an indication of the starch's suitability as a thickening agent in foods, and as a finishing agent in the textile and paper industries. Pasting characteristics are commonly evaluated using instruments such as a visco- amylograph or a rapid visco analyzer. In addition, rotational rheometers and other viscometers are employed, in which viscosity is continuously recorded with respect to temperature changes[19].

Using a rapid visco analyzer, several pasting parameters are typically determined: peak viscosity (PV), final viscosity, setback viscosity, breakdown viscosity, pasting temperature, and peak time. During this test, starch is mixed with water and allowed to hydrate rapidly upon heating. It is then maintained at a constant temperature for a specified period before being cooled to evaluate its pasting properties[20].

RPM	VISCOSITY @ 75°C	VISCOSITY @ 50°C
10	1110	1380
20	710	870
30	510	650
40	370	480
50	240	320

Fig.2. This table measures the viscosity (in centipoise) of a 5% starch paste at two different temperatures (75°C and 50°C) and at different RPM (Revolutions Per Minute) settings of the viscometer.

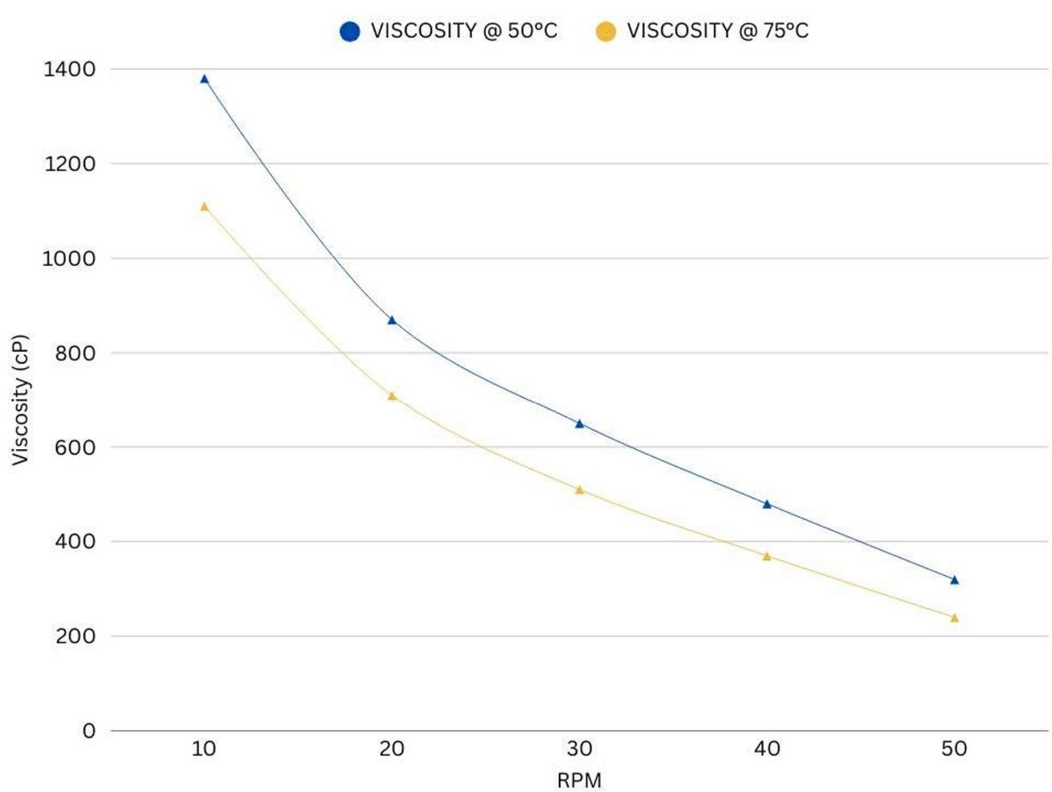

Fig.3.Graph of Viscosity vs Temperature.

As heating progresses, viscosity is increased due to the swelling of starch granules-a process which reflects the pasting behavior. The temperature at which the viscosity begins to rise is termed the pasting temperature. Viscosity continues to increase until a balance is reached between granule swelling and collapse, resulting in the peak viscosity (PV). PV is often used to reflect the extent of swelling or water-binding capacity of starch, which is frequently correlated with the final product quality. A subsequent reduction in viscosity, known as breakdown, is observed due to granule disintegration[21],[22]. This parameter is used to indicate the stability of starch during cooking.

This report presents the viscosity behaviour of 5% starch paste measured using a viscometer (Spindle No.3, RV) at different temperatures (75°C and 50°C) and various RPM settings. It includes an additional column – Percentage (%) – which appears to represent the relative viscosity drop (%) or change at each RPM compared to the initial reading (typically at 10 RPM). The viscosity (in centipoise) was recorded, along with the percentage decrease compared to the initial reading (at 10 RPM).

H. Applications

Our synthesized rice starch, being gluten-free, is highly suitable for individuals with gluten intolerance or sensitivity. Owing to its unique gelling and thickening properties upon heating, it serves as a vital ingredient in the food sector. Rice, especially in Asian countries such as Malaysia, Indonesia, and Thailand, is a staple crop primarily due to its rich starch content[23]. Our synthesized rice starch has been employed effectively to impart thickening and gelling characteristics in various food formulations. Structurally, starch is an insoluble carbohydrate composed of α-glucose polymers, primarily consisting of amylose and amylopectin. These components play a critical role in the starch's functionality, influencing factors such as digestibility, texture, and processing behavior[24].

In our study, the rice starch synthesized and characterized was found to be highly functional across multiple applications. The amylose-to-amylopectin ratio of our starch directly influenced the cooking quality, digestibility, and sensory characteristics of the end products[25],[26]. Common processed food items such as bread, cookies, pasta, pastries, noodles, and breakfast cereals were effectively enhanced using our synthesized starch. The rheological properties, such as pasting behavior, retrogradation, and viscosity, determined using our starch sample, significantly contributed to the overall appearance, stability, and quality of the final food products[27]. Approximately 50–55% of an individual's daily caloric intake is derived from carbohydrate-based foods, highlighting the critical role of starch as a dietary component. Our rice starch proved to be a powerful thickening and stabilizing agent, especially in baby foods and low-allergen applications due to its neutral taste and hypoallergenic nature[28]. In baked goods, our synthesized rice starch contributed to improved moisture retention, structure, and fiber enrichment. It also helped in reducing the hardness of sponge cakes compared to traditional wheat flour. Our rice starch has been successfully used to produce high-fructose rice syrup, particularly in industrial food applications[29].

Additionally, our starch demonstrated excellent performance in stabilizing emulsions, enhancing gelling properties, and serving as a multifunctional additive in the food industry. It was effectively utilized in soups, sauces, gravies, ice creams, frozen desserts, salad dressings, snacks, herbs and spice blends, noodles, chewing gums, and condiments[30]. Its fine granule size mimics fat globules, making it an ideal fat replacer in dairy products, baked goods, and processed meats .In gluten-free formulations, our synthesized starch provided superior structure and moisture balance to products like cakes and cookies. It improved the crispiness of fried products more efficiently than conventional maize or potato starch, making it ideal for deep-fried and Asian cuisine applications[31],[34].

Beyond the food industry, our rice starch found extensive use in other sectors. In the paper coating industry, it improved tensile strength, tear resistance, and printability while reducing moisture absorption, thereby preventing curling and warping[32]. In cosmetics, it added texture, reduced oiliness, calmed irritated skin, and served as a matte finish agent in creams, powders, and deodorants. As a non-toxic adhesive, it was effective in bookbinding and personal care product formulations[33]. In the pharmaceutical industry, our rice starch acted as a binder and disintegrant in tablets and capsules, serving as a safe and effective excipient that supported controlled drug release and enhanced formulation stability[35]. Environmental applications included its use as a coagulant in wastewater treatment and as a soil enhancer to promote microbial growth and improve fertility[36]. In the textile industry, it was employed for yarn sizing, improving fiber strength and smoothness during weaving, and ensuring accurate dye dispersion in printing[37].

IV. CONCLUSION

Rice starch, which constitutes nearly 90% of polished rice grain weight, plays a vital role across both food and industrial applications due to its functional versatility and favorable physicochemical properties.

Structurally composed of amylose and amylopectin, rice starch exists as semi-crystalline granules that are notably smaller than those from other sources. These unique characteristics, along with its naturally gluten-free and hypoallergenic nature, make rice starch highly desirable for specialized formulations. Although traditionally extracted through alkaline methods that may pose environmental concerns, the current study demonstrates that properly controlled traditional techniques can still yield high-purity rice starch, maintaining its integrity and enhancing its functional quality. We used classical analytical approaches to successfully characterize rice starch properties such as moisture, protein, fat, fiber, ash, and total starch content, confirming its suitability for a wide range of applications. Rice starch undergoes structural transitions such as gelatinization, retrogradation, and pasting during thermal processing, which significantly influence its texture and performance. Importantly, while rice starch forms weaker protein–fat bonds compared to corn or maize, this does not negatively impact its digestibility, texture, or thermal behavior during food processing. Additionally, rice starch exhibits notable commercial potential due to its application in cosmetics, textiles, paper, photography, and bioplastics. Its ability to form porous spherical aggregates when spray-dried makes it valuable for encapsulation and controlled release systems, adding further relevance in advanced food and pharmaceutical formulations.

Overall, this study reinforces that rice starch is a highly functional, high-quality biopolymer, with strong promise for sustainable, clean-label, and innovative product development across various industries.

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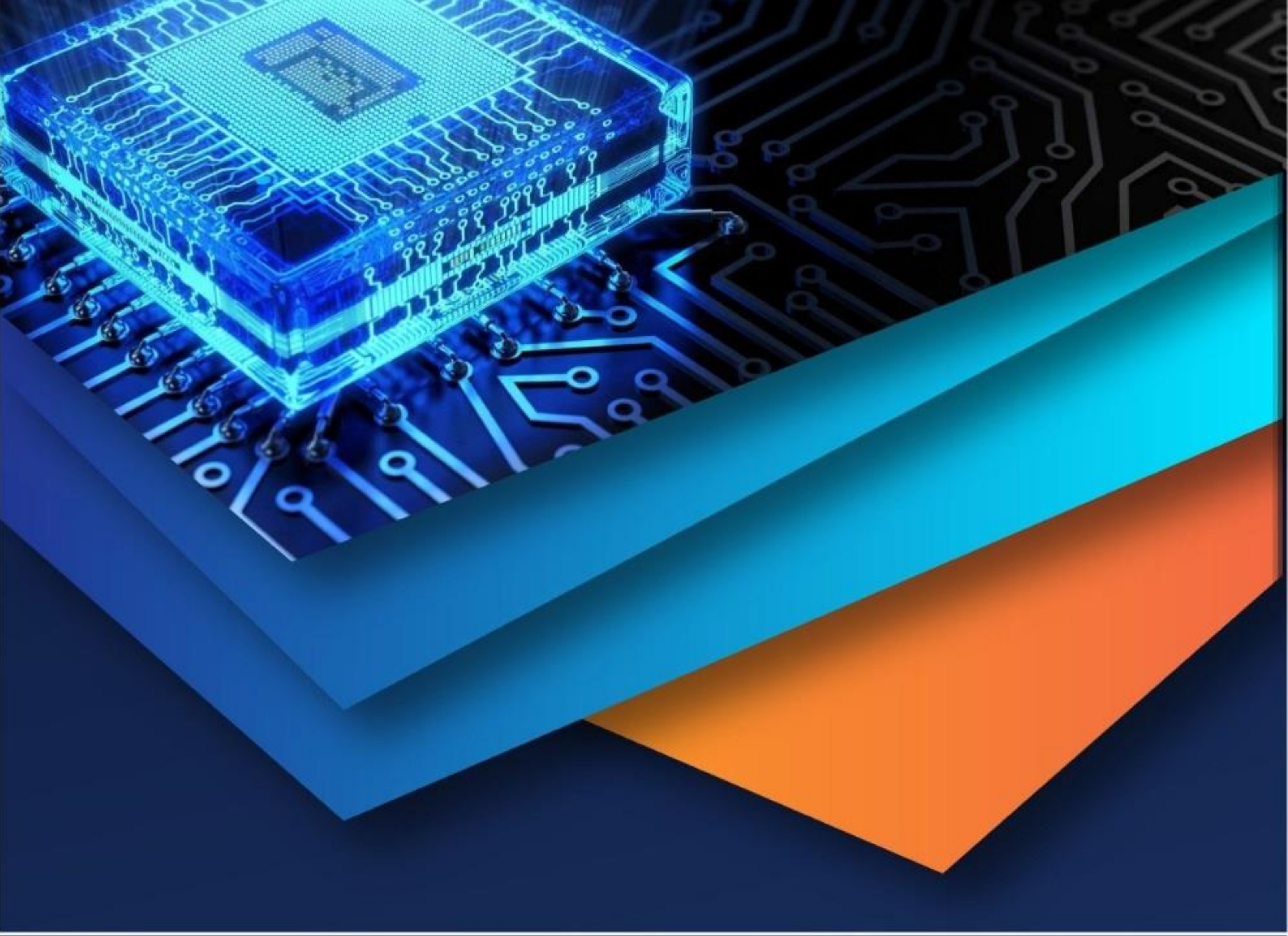

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