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Physicochemical and Functional (Performance) Perspective of Plant Based Starches: A Review

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1. ABSTRACT:

Starch is one of the most abundant biopolymers found in higher plants and is widely used in the food, pharmaceutical, textile, and biodegradable packaging industries (Singh et al., 2019; BeMiller, 2020). Among various botanical sources of starch, certain species are gaining increasing attention due to their distinctive physicochemical and functional characteristics. These are potato, cassava, banana, rice, maize, and sweet potato starches. (Zhang et al., 2021).

Potato starch is known for its high paste clarity, high swelling power, and superior viscosity, which make it more suitable for processed food formulations and thickening applications (Xu et al., 2021; Wang et al., 2022). Cassava starch finds utility for its neutral flavor, low gelatinization temperature, and versatile application potential in both food and non-food industrial sectors (Moorthy et al., 2018; Chamorro et al., 2025). Maize starch is widely prized due to its stable pasting behaviour and thermal resistance in food and packaging applications (Tester et al., 2004; Liu et al., 2020). Rice starch, since it has a fine granule size and smooth texture, is preferred in gluten- free and pharmaceutical formulations (Jane et al., 1999; Shoukat et al., 2020). Sweet potato starch exhibits high swelling power and paste viscosity, making it effective as a thickening agent in food systems (Moorthy et al., 2002; Ghoshal et al., 2019).

Banana starch, especially what is extracted from unripe fruits, contains a high proportion of resistant starch and amylose. Amylose provides functional health benefits such as reduced glycemic response. It also improves gut health, making it suitable for the development of low-glycemic and dietary fiber-enriched food products (Zhang et al., 2019; Munir et al., 2024).

This review carries out a comparative study on the structural properties, gelatinization behavior, digestibility, and industrial applications of potato, cassava, and banana starches, while summarizing recent literature and highlighting further research needs in the future in terms of starch extraction, modification, and application development (Subroto et al., 2022; Guo et al., 2023).

Keywords: Starch, potato, cassava, banana, rice, maize, sweet potato, equipment, structure, size, comparison.

2. INTRODUCTION:

Starch acts a natural carbohydrate reserve in plants. It primarily finds storage in roots, tubers, seeds, and fruits (Singh et al., 2019; BeMiller, 2020). Several starches' composition can be broken down into two polysaccharide fractions: amylose, a predominantly linear molecule, and amylopectin, a highly branched polymer. The latter's relative proportions significantly influence starch behavior during cooking, processing, and digestion (Zhang et al., 2021; Wang et al., 2022).

There exists a considerable variance in the morphology and functionality of starch. The botanical source of a given starch determines its granule size, shape, crystalline structure, gelatinization characteristics,

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pasting behavior, and enzymatic digestibility (Copeland et al.,

2009; Subroto et al., 2022). Whereas, variations in are caused due corresponding differences in swelling power, viscosity, thermal stability, and retrogradation tendencies. (Xu et al., 2021; Guo et al., 2023).

Understanding source-specific differences in starch properties is essential for selecting suitable starches for food processing, pharmaceutical formulations, and industrial applications, including biodegradable materials (BeMiller & Whistler, 2019; Chamorro et al., 2025).

The subsequent section introduces starches extracted from potato, cassava, banana, rice, maize and sweet potato on an indivudual basis. Special emphasis is placed on their structural characteristics, physicochemical properties, and functional relevance based on recent scientific literature (Moorthy et al., 2018; Munir et al., 2024).

2.1 **POTATO STARCH:** Potato starch, extracted from the tubers of *Solanum tuberosum*, has attracted considerable research interest due to its distinctive granular morphology and superior functional characteristics, which can be attributed to its relatively high starch concentration, accounting for approximately 15–24 % on a fresh weight basis and 60–80 % of the tuber dry matter, depending on cultivar and growing conditions (Singh et al., 2019; BeMiller et al., 2020). Potato starch granules are among the largest observed in commercially available starches. Their diameters reach up to 100 µm. This high degree of diameter length contributes to its high swelling power and capacity to form highly viscous pastes upon gelatinization (Singh et al., 2019). Large granule size results in the formation of translucent pastes. Potato starch particularly suitable for food systems precisely for this reason, where clarity is a trait which is desired (Xu et al., 2021). Additionally, there is the presence of naturally occurring phosphate monoesters. These monoesters are the reason why we find enhanced water-binding capacity and paste viscosity (BeMiller et al., 2020). Because of these functional properties, potato starch is widely utilized in soups, sauces, bakery fillings, noodles, and the development of biodegradable films (Wang et al., 2022). But in spite of having these advantages, native potato starch usage is limited due to poor freeze–thaw stability and susceptibility to retrogradation during storage. To bypass these hurdles, physical modification approaches, including heat–moisture treatment and annealing, have been tried out. Studies have shown them to improve thermal stability and functional performance (Subroto et al., 2022). Even more recent demonstrations show that combined enzymatic and physical modification strategies further enhance storage stability. These align with the end goal, which is to expand the industrial applicability of potato starch (Guo et al., 2023).

2.2 **CASSAVA STARCH:** Cassava starch is extracted from the tubers of *Manihot esculenta* species. Cassava starch is one of the most produced starches worldwide (quantity-wise). This is because it is fairly uncomplicated to extract starch from its tuber roots. Therefore, they are staple particularly in tropical and subtropical regions. Cassava roots contain a very high starch content. A typical cassava tuber contains a starch content percentage ranging anywhere between 70 and 85 % on a dry weight basis (Moorthy et al., 2018; Otekunrin et al., 2020). The method of Cassava starch production is also cost-effective and it makes significant contributions to both food and non-food industrial sectors (Moorthy et al., 2018; Otekunrin et al., 2020). Cassava starch granules are small to medium in size, ranging from approximately 5 to 35 µm. It also has low lipid and protein contents, which provide a neutral flavor and odor to the starch (Wang et al., 2019). Functionally, cassava starch exhibits a relatively low gelatinization temperature, contributing to reduced energy requirements during thermal processing (Chamorro et al., 2021). Its ability to form smooth, cohesive, and stable pastes has led to widespread application in bakery and confectionery products, as well as in paper coating, adhesive formulations, and textile sizing (Silva et al., 2021). But, poor viscosity stability and low freeze–thaw resistance are some of its drawbacks. Chemical modification techniques including oxidation and cross-linking have been investigated to offset its disadvantages, resulting in improved functional performance (Mendes et al., 2022) and fermentation-assisted treatments have been shown to enhance thermal stability and broaden the industrial applicability of cassava starch (Ibrahim et al., 2023).

2.3 BANANA STARCH: Banana starch is sourced from unripe green bananas (*Musa* spp.). This variety of starch has grabbed eyeballs of researchers due to its high amylose and resistant starch content. The starch yield from unripe banana pulp typically ranges from 16 to 25 % on a fresh weight basis, depending on cultivar and extraction method (Zhang et al., 2019). Banana starch extracted from unripe fruits contains a substantial proportion of resistant starch that resists digestion in the small intestine. This aspect, in turn, results in reduced glycemic response and improved metabolic health (Zhang et al., 2019). The resistant starch fraction undergoes fermentation in the colon, producing short-chain fatty acids that promote gut health and support beneficial microbiota (Munir et al., 2024). In terms of functionality, banana starch exhibits moderate swelling power and strong gel-forming ability, making it suitable for use in functional foods, gluten-free formulations, and textural modification applications (Guo et al., 2023). Processing conditions play a critical role in determining starch quality, as milder extraction methods help preserve native granular structure and retain higher resistant starch levels (BeMiller et al., 2020). Recent studies have focused on optimizing extraction techniques and evaluating the nutritional and therapeutic benefits of banana starch, highlighting its strong potential for incorporation into nutritional and therapeutic food products beyond conventional starch applications (Munir et al., 2024).

2.4 **MAIZE STARCH:** Maize starch is obtained from the endosperm of *Zea mays* kernels. It is one of the most widely utilized starches in food and non-food industries. Maize grains contain a high proportion of starch, typically accounting for 65–75 % of the kernel dry weight, which supports its large-scale industrial usage (Tester et al., 2004; Singh et al., 2010). It is characterized by polygon-shaped granules with sizes typically ranging from 5 to 25 µm and exhibits moderate swelling power and paste clarity (Tester et al., 2004). The functional behavior of maize starch is primarily governed by its amylose-to-amylopectin ratio, which influences gelatinization, retrogradation, and viscosity development (Singh et al., 2010). Owing to its predictable pasting behavior and thermal stability, maize starch finds extensive applications in soups, sauces, confectionery, paper sizing, and biodegradable films. In recent years, research has increasingly focused on modifying maize starch through enzymatic, heat–moisture, and chemical treatments to improve its digestibility profile, storage stability, and film-forming properties (Liu et al., 2020).

2.5 RICE STARCH: Rice starch is extracted from the grains of *Oryza sativa* and is distinguished by its relatively small and angular granules, typically measuring between 2 and 8 µm (Jane et al., 1999). Rice grains contain a high starch fraction, generally ranging from 60 to 83 % of dry matter, depending on variety and degree of milling (Singh et al., 2011). The fine granule size of rice starch contributes to smooth paste texture and low opacity, making it particularly suitable for applications requiring delicate mouthfeel and uniform consistency (Singh et al., 2011). Rice starch generally exhibits lower swelling power and higher gelatinization temperature when compared to tuber starches, which can be attributed to its compact granular structure and starch–protein interactions (Sodhi & Singh, 2017). Due to its bland flavor, hypoallergenic nature, and clean-label appeal, rice starch is widely used in baby foods, gluten-free products, pharmaceutical formulations, and cosmetic applications. Current research trends emphasize improving rice starch functionality through alkaline extraction, enzymatic treatments, and physical modification techniques to enhance paste stability and processing performance (Shoukat et al., 2020).

2.6 SWEET POTATO STARCH: Sweet potato starch is derived from the tubers of *Ipomoea batatas* and represents an important alternative starch source, particularly in tropical and subtropical regions. Sweet potato roots typically contain 10–30 % starch on a fresh weight basis, with significant variation among cultivars and growing conditions (Moorthy et al., 2002; Zhu et al., 2015). The starch granules are typically round to polygonal in shape and possess relatively high swelling power and paste viscosity, which contribute to desirable thickening properties (Moorthy et al., 2002). Sweet potato starch demonstrates functional behavior intermediate between cereal and other tuber starches, with amylose content influencing its gelatinization and gel-forming ability (Zhu et al., 2015). These characteristics make it suitable for use in noodles, sauces, bakery products, and emerging biodegradable materials. Recent studies have focused on modifying sweet potato starch through heat treatment and physical modification to enhance thermal stability, reduce retrogradation, and broaden its industrial applicability (Ghoshal et al., 2019).

3. LITERATURE REVIEW:

3.1 POTATO STARCH:

Cheng et al. (2019) tested the impact of heat- moisture treatment on the structure of potato starch granule. They found that an increase in the gelatinization temperature and a marked reduction swelling capacity, post-treatment and that this modification enhances the thermal stability of the granules, making it a better option for food processing under high temperatures. Li and Wang (2020) examined the phosphorylation of potato starch and demonstrated that the addition of phosphate groups led to a better paste clarity and

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viscosity stability. These two characteristics, in turn lead to better transparency and a smoother food texture, making them desirable ingredients in soups and sauces.

Deng et al. (2021) examined the efficacy of annealing as a modification method, arriving to the conclusion that annealed starch granules exhibit enhanced molecular ordering. This would result in lower susceptibility to enzymatic digestion, making its application suitable in the development of diabetic-friendly and low-glycemic foods while Miao et al. (2021) exploited enzymatic debranching to modify amylopectin structure, which increased gel consistency and firmness, improving texture quality in products li+ke noodles and confectionery gels.

Xu et al. (2022) researched on ultrasonic treatment and reported that the ultrasonic energy led to reduced granule size and increased cold-water solubility. This makes potato starch suitable for instant beverages and instant sauce mixes. Kaul et al. (2022) conducted a comparative study of microwave- treated potato starch and its native counterpart. Their observation reflected that microwaving maximised pasting properties and thickening efficiency. Zhang et al. (2023) used acid hydrolysis method to convert potato starch into nano-starch particles and demonstrated that the nano-starch variant showcased excellent film- forming ability, meaning it could find potential use in biodegradable packaging and edible coatings. Rahman and Kumar (2023) studied freeze–thaw behavior and found the resistance cross-linked potato starch to syneresis and maintenance of gel stability, making it suitable for frozen bakery and dessert formulations.

3.2 CASSAVA STARCH:

Cassava starch has repeatedly found itself as an area of research due to its low cost and suitability for diverse food and non-food applications. Wang et al. (2019) evaluated the cassava starch granule structure in detail They postulated that its small granule size translated to its smooth paste texture and high digestibility. Otekunrin et al. (2020) highlighted that demand for cassava starch had increased worldwide due to its neutral flavour and adaptability in the bakery and confectionery industries. Chamorro et al. (2021) conducted a study on the physicochemical characterisation of cassava starch, focusing on its low gelatinisation temperature, which increases energy saving during industrial food processing. Mendes et al. (2022) used fermentation-assisted modification, revealing that fermentation leads granule crystallinity, enhancing viscosity and enabling cassava starch to perform well as a thickener in dairy and dessert products. Dlamini and Musa (2022) studied cassava starch in adhesive formulations and found that chemically modified cassava starch had an improved bonding strength compared to native starch.

In 2023, Ibrahim et al. demonstrated improved clarity and reduced retrogradation in cassava starch gels due to oxidation modification, which is advantageous for clear sauces and confectionery glazes. Tanchotikul et al. (2023) from their study of cross-linked cassava starch, confirmed that cross-linking prevents breakdown during high shear cooking. In 2024, Haruna et al. examined cassava starch in biodegradable film formation. They concluded that plasticized cassava starch films generally exhibited good tensile strength and biodegradability, suggesting application in eco- friendly packaging.

3.3 BANANA STARCH:

Banana starch provides functional and nutritional advantages due to its high amylose and resistant starch content, attracting interest from researchers. Kaur et al. (2019) reported that the high resistant starch fraction of unripe bananas contributes to slow digestion, making banana starch a suitable ingredient for preparing low glycemic foods. Nandana and Moorthy, (2020) in their comparative study of banana starch with potato and cassava starch and noticed that banana starch forms firmer gels due to its higher amylose content, making it useful in products where shape retention and firmness are required. In 2021, Pérez et al. in an attempt to optimize banana starch extraction, found that lower processing temperatures preserve native granular structure, leading to improved pasting performance. Rodríguez et al. (2021) investigated the effect of heat-moisture treatment and observed increased gelatinization temperature and reduced swelling, providing improved stability of starch during cooking. In 2022, Herrera et al. studied banana starch in snack formulations and attributed the increased expansion and crispness in extruded snacks to the usage of banana starch. Costa et al. (2023) incorporated banana starch into gluten-free bread and reported that it led to enhanced texture, moisture retention, and shelf life.

Yuan et al. (2024) compared different banana cultivars and identified significant differences in their amylose/amylopectin ratio, which factors in digestibility and gel strength. In 2024, Adjei et al. studied banana resistant starch as a prebiotic ingredient and reported better formation of gut microbes. Kumari and Reddy (2025) reported that banana starch nanoparticles enhance solubility and dispersibility in beverages. Davila et al. (2025) proposed the usage of banana starch blended with biopolymers like chitosan to produce food- grade biodegradable packaging films.

3.4 MAIZE STARCH:

Tester et al. (2010) explored the effects on heat and moisture treatment on starch from maize and stated that there is an increase in gelatinisation temperature along with swelling power and solubility. Liu et al. (2018) investigated chemical modification through acetylation and reported enhanced paste clarity, reduced retrogradation, and improved freeze thaw stability of maize starch gels. These are beneficial in the frozen food systems. Zheng et al. (2020) explored dual modified maize starch by using phosphorylation under the heat treatment and stated that the gel strength and viscosity is improved.

3.5 RICE STARCH:

Sodhi and singh (2016) examined the annealing treatment of the rice starch and declared that crystalline stability is enhanced and swelling power is reduced, improving the paste stability during prolonged heating. Shoukat et al. (2016) explored the methods of alkaline extraction and observed that the mild alkaline treatment will enhance the clarity and viscosity of the paste while preserving granular integrity. Chung et al. (2019) investigated the enzymatic modification using pullulanase and identified partial debranching of amylopectin, increase the gel firmness and reduced syneresis, making the starch suitable for gel biased foods.

3.6 SWEET POTATO STARCH:

Zhu et al. (2014) claimed that gelatinization temperature is increased and retrogradation tendency is reduced, enhancing storage stability in processed foods. Ghoshal et al, (2017) observed crystalline perfection and thermal stability of starch granules is improved. It is useful for high temperature foods such as noodles and bakery products. Wang et al. (2014) examined acid hydrolysis of sweet potato starch and reported reduction in molecular weight and improved film forming properties. Cheng et al. (2022) explored ultrasound and enzymatic treatment by dual modification and found enhanced solubility, reduced granule size and improved paste stability. These properties expand the scope of sweet potato starch for use across food, pharmaceutical, and biodegradable material industries.

4. METHOD OF STARCH EXTRACTION:

4.1 POTATO STARCH:

Starch is extracted from potato by the process of mechanical disintegration, followed by purification and drying. First, fresh potato tubers are thoroughly washed thoroughly such that mud and microbial contaminants are removed. Next, peeling is done to prevent phenolic compounds and pigments from affecting starch color, as the potato skin contains oxidizing enzymes that may cause browning (Kaul et al., 2022). After peeling, the potatoes are grated into a pulp form rupturing parenchymal cell walls to release the starch granules embedded in the intracellular matrix. (Cheng et al., 2019)

The pulp extracted is mixed with cold water to prevent gelatinisation and is followed by filtration through a muslin cloth or fine sieve. This is done to separate the fibrous residue from the starch milk (Li & Wang, 2020). The filtrate is then allowed to sediment, during which heavier starch granules settle at the bottom and the supernatant containing soluble sugars and proteins is decanted. The sediment is washed multiple times to remove residual impurities(Deng et al., 2021). The purified wet starch undergoes drying at controlled temperatures below 45°C to prevent premature gelatinization and degradation of granule structure (Miao et al., 2021). The dried starch which is obtained at this stage is finally milled and sieved to produce a uniform powder ready for use in food and industrial formulations.

4.2 CASSAVA STARCH:

Cassava starch extraction begins with processing of fresh roots immediately after harvest to avoid enzymatic hydrolysis and cyanogenic glycoside release, which can occur if the roots are stored for too long (Wang et al., 2019). The cassava roots are washed carefully and then the outer periderm and cortex, which contain higher concentrations of cyanogenic compounds, are removed by peeling (Otekunrin et al., 2020). Using a rotary grater or a hammer mill, the peeled roots are then chopped and finely grated to release starch granules from the storage cells (Chamorro et al., 2021). The resulting grated pulp is mixed with water to form a slurry and passed through filtration cloth or a centrifugal extractor to filter out any insoluble fibrous material (Silva et al., 2021). The extract is allowed to stand such that the starch granules sediment at the bottom, while water-soluble components remain in the supernatant and are removed by decantation (Mendes et al., 2022). The starch sediment is washed repeatedly to improving purity and safety by removing cyanogenic residues and non-starch polysaccharides (Dlamini & Musa, 2022). It is then dries around 40–50°C to preserve granule morphology and functional properties. The dried starch is uniformly milled and stored in airtight containers to prevent moisture absorption and contamination by microbes (Ibrahim et al., 2023).

4.3 BANANA STARCH:

As discussed previously, unripe green bananas are preferred for starch extraction because of their high starch and low sugar content (Kaur et al., 2019). The bananas are washed and peeled, and the pulp is immediately immersed in cold water after slicing to prohibit polyphenol oxidase activity which causes enzymatic browning (Nandana & Moorthy, 2020). The banana pulp is then subjected to homogenisation using a blender or mechanical grinder, releasing starch granules from the parenchyma cells (Pérez et al., 2021). This homogenised pulp is then mixed with excess cold water and filtered or sieved to separate the fiber from the starch slurry (Rodríguez et al., 2021). The filtrate, which is then allowed to settle for sedimentation, forms a compact layer of starch granules at the bottom. After decanting the supernatant, the sediment is washed several times to remove soluble sugars, tannins, and pigments (Herrera et al., 2022).The reuslting starch sediment is oven-dried or tray- dried to maintain granule integrity and resist gelatinization at 40–45°C (Costa et al., 2023). Post drying, the starch is stored in airtight containers after being ground into fine powder. This final step is carried out to prevent the reabsorption of moisture (Yuan et al., 2024).

4.4 MAIZE STARCH:

Maize starch is extracted from maize kernels using a wet milling process involving steeping, mechanical disintegration, and purification. Initially, dried maize kernels are thoroughly cleaned to remove dust, broken kernels, and other foreign matter. The cleaned kernels are then steeped in distilled water or dilute sodium hydroxide solution (0.05–0.2%) for several hours to soften the endosperm and weaken starch–protein interactions, thereby facilitating starch release during milling (Mistry et al., 2009).

After steeping, the softened kernels are wet- ground using a laboratory grinder or blender in the presence of excess water to rupture the endosperm matrix and liberate starch granules embedded within the protein network (Tester et al., 2004). The resulting slurry is passed through muslin cloth or fine sieves to remove coarse fiber and germ residues. The filtrate, commonly referred to as starch milk, is allowed to sediment or is centrifuged to separate starch granules from soluble proteins and non-starch components (Singh et al., 2010). The starch sediment is washed repeatedly with distilled water to improve purity. In some extraction protocols, protease treatment is applied prior to washing to enhance protein removal and starch yield (Liu et al., 2020). The purified starch is dried at temperatures below 50 °C to prevent gelatinization and is finally milled into a fine powder for further use.

4.5 RICE STARCH:

Rice starch extraction is generally performed using an alkaline wet milling technique to facilitate efficient removal of protein impurities. Broken rice grains are first thoroughly washed and soaked in dilute sodium hydroxide solution (0.05–0.3%) for 12–24 hours to solubilize proteins and loosen starch granules (Zhang et al., 2017). The soaked grains are then wet-ground with distilled water to obtain a homogeneous slurry. The slurry is filtered through muslin cloth or a fine sieve to remove fibrous material, and the filtrate containing starch milk is allowed to sediment or centrifuged to recover the starch fraction (Sodhi & Singh, 2017). The supernatant is carefully decanted, and the starch sediment is washed repeatedly with distilled water until residual alkali and protein impurities are removed. Neutralization is subsequently carried out using dilute hydrochloric acid to adjust the pH to near neutrality (Jane et al., 1999). The purified rice starch is dried at controlled temperatures below 50 °C to preserve granular integrity and then milled into a uniform powder suitable for food and industrial applications.

4.6 SWEET POTATO STARCH:

Sweet potato starch is extracted using a wet extraction method involving mechanical disruption, washing, and sedimentation. Fresh sweet potato tubers are washed thoroughly, peeled, and cut into small pieces to remove surface contaminants and prevent enzymatic browning (Moorthy et al., 2002). The peeled tubers are grated or blended with distilled water to form a pulp, thereby rupturing parenchymal cell walls and releasing starch granules. The pulp is filtered through muslin cloth to separate fibrous residues, and the filtrate is collected as starch milk. The filtrate is allowed to stand undisturbed to permit sedimentation of starch granules, while soluble sugars and proteins remain in the supernatant and are removed by decantation (Ghoshal et al., 2019). The starch sediment is washed multiple times with distilled water to enhance purity. In some studies, sodium chloride or buffer solutions are used during washing to improve starch recovery and reduce discoloration (Zhu et al., 2015). The washed starch is dried at temperatures below 45–50 °C to prevent gelatinization and is subsequently milled into a fine powder for storage and further application.

5. COMPARATIVE PROPERTIES OF STARCH FROM DIFFERENT BOTANICAL SOURCES:

Depending on the botanical source, there exists a wide variation in the chemical and physical properties of starch. This impacts starch granule structure, amylose amylopectin ratio, gelatinisation behaviour, and functional performance in food systems. Potato, cassava, and banana starches differ significantly in their composition at the molecular and morphological levels, resulting in distinct technological applications.

5.1 AMYLOSE AND AMYLOPECTIN CONTENT:

The proportion between the presence of amylose and amylopectin determines gel strength, digestibility, and pasting behaviour of a given starch. Potato starch contains amylose in moderation, typically ranging between 20– 25%, and possesses a high degree of amylopectin branching (Kaul et al., 2022), whereas cassava starch has a relatively lower level of amylose (17–20%), leading to smooth and cohesive paste texture (Wang et al., 2019). In contrast, banana starch, extracted from unripe fruit in particular, exhibits a higher amylose level (25–35%) and a substantial resistant starch fraction, due to which it has slower digestibility and firmer gel formation (Kaur et al., 2019; Yuan et al., 2024).

5.2 GRANULE MORPHOLOGY & SIZE:

Potato starch granules can be as large as up to 100 µm, and are oval or spherical in shape. They possess distinct birefringence, which improves properties such as swelling and hydration (Cheng et al., 2019). Cassava starch granules, on the other hand, are smaller (5–35 µm) and more uniform in nature, leading to the formation of smooth gel textures and easy dispersion in aqueous systems (Chamorro et al., 2021). In contrast to the above two, banana starch granules show a wider size distribution (10–50 µm) albeit with irregular polyhedral shapes. This creates higher structural rigidity and reduced swelling compared to potato starch (Pérez et al., 2021).

5.3 GELATINISATION & PASTING PROPERTIES:

Potato starch, due to the presence of phosphate monoesters in amylopectin, is characterised by its high swelling power and viscosity, which further results in high gelatinisation temperatures and strong paste clarity (Miao et al., 2021). However, cassava starch exhibits lower gelatinisation temperatures and lower paste stability during high shear cooking. This can lead to breakdown unless modified appropriately (Silva et al., 2021) while banana starch tends to undergo gelatinisation even at moderate temperatures. However, banana starch forms firm and elastic gels due to its higher amylose content.(Nandana & Moorthy, 2020; Costa et al., 2023).

5.4 WATER ABSORPTION AND SWELLING POWER:

Owing to the presence of surface phosphate groups, granules which are of large size, very high water absorption and swelling can be seen in potato starch, which enhances hydration (Li & Wang, 2020). The crystalline structure of starch significantly influences its thermal stability, enzymatic susceptibility, and functional performance. Potato starch predominantly exhibits **a** B-type crystalline pattern**,** which is associated with a more open hexagonal structure and higher water incorporation within the granule matrix (Singh & Kaur, 2020). This crystalline arrangement contributes to its high swelling capacity and susceptibility to gelatinisation. Cassava starch, in contrast, mainly displays an A-type crystalline structure**,** which is more compact and densely packed, resulting in relatively lower hydration and faster enzymatic hydrolysis (Zhang et al., 2021). Banana starch generally exhibits a C-type polymorphism**,** representing a mixture of A- and B-type crystallinity. This mixed crystalline nature contributes to its enhanced resistance to enzymatic digestion and greater thermal stability, making it suitable for functional and low-glycaemic food applications (Zhu et al., 2022).

5.5 THERMAL STABILITY AND RETROGRADATION BEHAVIOUR:

Thermal behaviour and retrogradation tendencies are critical factors affecting starch performance during processing and storage. Potato starch demonstrates relatively high thermal stability due to its phosphate ester content, but it is also prone to retrogradation upon cooling, which can result in syneresis during refrigerated storage (Kim et al., 2020). Cassava starch shows lower retrogradation rates compared to potato starch, attributed to its lower amylose content and uniform granule structure, making it desirable for products requiring extended shelf stability and freeze–thaw resistance (Srichuwong et al., 2019). Banana starch, owing to its higher amylose concentration, exhibits a strong tendency toward retrogradation, leading to firmer gel structures and enhanced textural stability in processed foods (Ovando-Martínez et al., 2021).

5.6 DIGESTIBILITY AND RESISTANT STARCH FRACTION:

Digestibility is an important nutritional parameter that varies significantly among starch sources. Potato starch contains a moderate level of resistant starch, particularly in its native form, which can contribute to slower glucose release and improved gut health (Fuentes-Zaragoza et al., 2020). Cassava starch is generally more rapidly digestible due to its low amylose content and A-type crystalline structure, making it suitable for products requiring quick energy release (Almeida et al., 2022).

In contrast, banana starch, especially from unripe fruit is remarkably rich in resistant starch type II**,** which resists enzymatic digestion in the small intestine and undergoes fermentation in the colon. This property supports its application in functional foods targeting glycaemic control and prebiotic benefits (Tribess et al., 2019; Yuan et al., 2024).

5.7 FUNCTIONAL PERFORMANCE IN FOOD SYSTEMS:

The combined chemical and physical properties of starch dictate its suitability for specific food applications. Potato starch is widely utilised as a thickening and binding agent in soups, sauces, and extruded products due to its high viscosity and paste clarity (Li et al., 2021). Cassava starch is preferred in products such as noodles, bakery fillings, and confectionery owing to its smooth texture, neutral flavour, and good film- forming ability (Silva et al., 2021). Banana starch, with its higher amylose content and resistant starch fraction, is increasingly incorporated into functional foods, gluten-free formulations, and low-glycaemic index products, where textural firmness and nutritional enhancement are required (Costa et al., 2023; Pérez et al., 2021).

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