

REVIEW PAPER

Arrowroot and Its Starch: Nutritional, Functional, and Technological Perspectives-A review

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Paper No.: 339

Received: 08-10-2025

Revised: 03-11-2025

Accepted: 23-11-2025

ABSTRACT

Arrowroot (*Maranta arundinacea L.*) is a traditional tropical tuber crop that has been long valued for its easily digestible starch and medicinal uses, yet it remains scientifically under-explored when compared with major root and tuber crops. In recent years, renewed interest in arrowroot has emerged due to its gluten free nature, low glycaemic response, and suitability for functional food and biodegradable material applications. This review presents a comprehensive view of arrowroot, covering its origin, botanical features, cultivation status, and production trends, along with a detailed discussion of its nutritional composition and starch characteristics. Special emphasis is given to the physico-chemical, functional, and rheological properties of arrowroot starch that govern its performance in food systems and non-food applications. The presence of bioactive compounds and dietary fibre, along with their potential health benefits, including digestive support and emerging immunomodulatory effects, is critically examined based on recent scientific datas. Advances in processing technologies and the development of value-added products such as gluten free foods, edible films, and sustainable packaging materials are also reviewed. The paper further highlights current research contributions from tropical research institutions and identifies key knowledge gaps related to varietal improvement, processing standardisation, and commercial scaling. Overall, this review underscores the potential of arrowroot as a multifunctional tuber crop capable of contributing to nutrition security and sustainable industrial development.

Keywords: *Maranta arundinacea*, underutilized tuber crops, arrowroot starch functionality, non-conventional starch sources, gluten free food systems, bioactive compounds, edible films, sustainable biopolymers

The word arrowroot is considered to originate from the Caribbean Arawak term “*aru-aru*,” meaning “meal of meals,” a phrase that reflects its historical significance as a highly valued and nourishing food among indigenous populations (Coelho *et al.* 2005). Botanically, arrowroot (*Maranta arundinacea L.*) is a perennial herbaceous tuber crop belonging to the family Marantaceae. The plant develops horizontally growing underground rhizomes that serve as the primary storage organs for starch accumulation. Although arrowroot is currently regarded as an underutilized crop in modern agricultural systems, it

has long held an important place in traditional diets and medicinal practices across tropical regions.

Arrowroot is native to the humid tropical areas of Central and South America, particularly the Caribbean islands and the Amazon basin. With time, its cultivation spread to various parts of the world, including India, Africa, the West Indies especially

How to cite this article: Vekhande, A.S. and Swami, S.B. (2025). Arrowroot and Its Starch: Nutritional, Functional, and Technological Perspectives-A review. *Int. J. Food Ferment. Technol.*, 15(02): 501-518.

Source of Support: None; **Conflict of Interest:** None



Jamaica-Indonesia, the Philippines, Sri Lanka, and other regions of Southeast Asia, where it adapted well to diverse agroclimatic conditions. Despite this broad geographical distribution, arrowroot continues to be grown largely on a small scale and remains a minor crop in most producing countries, including India.

In India, arrowroot is traditionally cultivated in tropical and subtropical regions, mainly within homestead gardens and smallholder farming systems. States such as Kerala, Tamil Nadu, and Odisha are known for its limited cultivation and traditional use, particularly in Ayurvedic preparations and folk medicine. Although arrowroot has not yet been commercialized in Maharashtra, the Konkan region has been identified as a suitable area for its potential expansion due to favourable red loamy soils, high organic matter content, and a moderately humid climate (ICAR-CTCRI Annual Report 2018; Singh and Kundu 2016). Under improved agronomic practices, yields ranging from approximately 20 to 35 tonnes per hectare have been reported in suitable environments (CTCRI Annual Report 2022). At the national level, arrowroot production in India remains relatively low, with estimates of about 5,000-6,000 tonnes annually, most of which is consumed domestically for culinary, medicinal, and small-scale processing purposes (Roy *et al.* 2020).

From a nutritional aspect, arrowroot is recognized as a carbohydrate-rich food with a high content of easily digestible starch. The rhizomes contain substantial starch reserves and are naturally gluten-free, making arrowroot suitable for individuals with celiac disease or gluten sensitivity. It is also regarded as a low glycemic index food, supporting its inclusion in diets aimed at managing blood glucose levels and diabetes. In Sri Lanka, arrowroot has been traditionally used in indigenous medicine and is locally known as “Hulankeeriyā” or “Aerukka,” where it is consumed for its digestive and restorative properties (Malki *et al.* 2023).

Beyond its conventional dietary use, arrowroot has gained increasing scientific attention due to its emerging functional and therapeutic attributes. Recent studies suggest that thermally processed arrowroot

starch extracts may exhibit immunomodulatory activity. For example, controlled heat treatment of arrowroot powder has been reported to enhance immunoglobulin M (IgM) production in cultured human immune cells, indicating its potential role in immune system stimulation (ICAR-CTCRI Press Release, November 2024). Such findings have contributed to renewed interest in arrowroot as a functional food ingredient rather than just a source of dietary energy.

Arrowroot starch has also found growing applications in both food and non-food industries owing to its distinctive physicochemical and functional characteristics. The starch extracted from arrowroot rhizomes is composed predominantly of carbohydrates, with very low levels of protein and lipids. Microscopically, arrowroot starch granules are generally oval to elongated in shape, possess smooth surfaces, and range in size from approximately 15 to 65 μm . The starch exhibits B-type crystallinity, which plays a key role in determining its swelling capacity, solubility, and digestibility (Kaur *et al.* 2010). These structural features contribute to its high paste clarity, relatively low gelatinization temperature (around 70–75°C), high water-holding capacity, and excellent thickening properties, making it particularly suitable for infant foods, dietary formulations, sauces, puddings, and other delicately textured food products (Singh *et al.* 2016).

The amylose content of arrowroot starch generally ranges between 17 and 23%, resulting in the formation of soft gels and high viscosity upon heating. This compositional characteristic supports its effective use as a stabilizer, thickener, and gelling agent in a variety of food systems (Moorthy 2002). When compared with starches derived from cassava, potato, or maize, arrowroot starch exhibits lower retrogradation tendencies and improved digestibility, attributes that are beneficial for both food and biomedical applications. Rheological studies have further shown that arrowroot starch gels display pseudoplastic and shear-thinning behaviour, properties that are advantageous during processing and product formulation (Kaur *et al.* 2010).

In recent years, arrowroot starch has emerged as a promising raw material for the development of biodegradable and edible films and coatings. Its natural film-forming ability, transparency, and relatively low oxygen permeability make it suitable for sustainable packaging applications. Arrowroot-based films can act as effective barriers to oxygen and carbon dioxide, thereby helping to extend the shelf life of minimally processed foods. However, similar to other starch-based films, arrowroot films tend to be brittle and require the addition of plasticizers such as glycerol, sorbitol, or polyethylene glycol to enhance flexibility and mechanical strength by reducing intermolecular hydrogen bonding (Souza *et al.* 2013; Soares *et al.* 2021; Abdillah and Charles 2021).

Apart from food packaging, arrowroot starch has shown potential in pharmaceutical applications as a tablet binder and disintegrant, as well as in biodegradable plastics, cosmetic formulations, and textile finishing processes. Its hypoallergenic nature, smooth texture, renewability, and biodegradability make arrowroot starch a promising alternative to synthetic polymers in environmentally sustainable industrial applications (Singh and Kaur, 2018).

Botanical and Morphological Characteristics of Arrowroot

1. Taxonomic Classification

Arrowroot (*Maranta arundinacea* L.) is a perennial monocot plant that grows from underground

rhizomes and belongs to the family Marantaceae under the order Zingiberales, genus *Maranta*, this species is of particular economic importance because of its high-quality starch and its ability to grow well under tropical climatic conditions (Purseglove, 1985; Brito *et al.* 2021). Fig. 1 shows the morphological features of arrowroot (*Maranta arundinacea* L.): (a) whole plant showing aerial parts; (b) underground rhizome used for starch storage.

2. Growth Habit and Life-Cycle

Arrowroot is a long-duration perennial crop, generally grown as an annual in agricultural systems. The plant exhibits an erect growth habit with pseudostems formed by overlapping leaf sheaths. Under favourable tropical conditions, the crop reaches maturity within 8–12 months after planting (Palanisamy *et al.* 2002). Vegetative propagation using rhizome is commonly practiced, ensuring uniform growth and stable yield.

3. Root and Rhizome Characteristics

The underground system consists of fibrous roots and fleshy rhizomes, which serve as the primary starch storage organs. Rhizomes are cylindrical to spindle-shaped, pale white internally, and covered with thin brownish scales. Starch is densely deposited within the parenchymatous tissues of the rhizomes, resulting in high starch recovery during processing. Rhizome size, branching, and maturity at harvest significantly



(a)



(b)

Fig. 1: Morphological features of arrowroot (a) whole plant showing aerial parts and (b) underground rhizome

influence starch yield. (Sandoval Gordillo *et al.* 2014; Brito *et al.* 2021).

4. Shoot and Leaf Morphology

The aerial portion of the plant comprises a soft, non-lignified pseudostem and large, simple leaves. Plant height generally ranges from 0.6 to 1.5 m depending on cultivar and growing conditions (Purseglove, 1985). Leaves are ovate to lanceolate, measuring approximately 15–30 cm in length, with a glossy green upper surface, prominent midrib, and parallel venation typical of monocotyledons. The broad lamina supports efficient photosynthesis, contributing to carbohydrate synthesis and translocation to the rhizomes (Nair, 1990).

5. Inflorescence and Reproduction

Arrowroot produces small, bisexual flowers arranged in terminal or axillary panicles. The flowers are usually white to pale purple in colour and are not of economic importance. Seed production is rare under cultivated conditions, and sexual reproduction plays a minimal role, as the crop is predominantly propagated vegetatively (Palanisamy *et al.* 2002).

6. Starch Granule Morphology

Arrowroot starch granules are predominantly oval to elongated, smooth-surfaced, and range in size from approximately 15 to 60 μm (Sandoval Gordillo *et al.* 2014). These granule characteristics contribute to high paste clarity, smooth texture, and good film-forming ability. Compared with cassava and potato starches, arrowroot starch exhibits finer granules and lower impurity levels, enhancing its suitability for food and pharmaceutical applications (Moorthy, 2002; Hoover, 2001).

7. Ecological Adaptability

Arrowroot is well adapted to humid tropical climates and performs well under partial shade, making it suitable for intercropping and agroforestry systems. This ecological flexibility enhances its potential for sustainable cultivation in diversified farming systems (Octavia *et al.* 2024).

Production Status of Arrowroot: Global and National Perspectives

Arrowroot (*Maranta arundinacea* L.) is recognized globally as a minor tuber crop, cultivated mainly in tropical and subtropical regions. Despite its historical significance and adaptability, it has not achieved large-scale commercial significance compared with major root crops such as cassava, potato, or yam. Its cultivation is largely small-scale, localized, and often integrated into home gardens, traditional farming systems, and agroforestry models (Brito *et al.* 2021; FAO, 2011).

1. Global Production Scenario

Arrowroot is cultivated in Central and South America, the Caribbean, Southeast Asia, Africa, and parts of Oceania. The Caribbean, particularly Jamaica and St. Vincent, is historically significant for commercial arrowroot starch production and export during colonial times (Purseglove, 1985). In Latin America, countries such as Brazil and Colombia grow arrowroot mainly for local consumption and starch markets.

In Southeast Asia, arrowroot cultivation is reported in Indonesia, the Philippines, Thailand, and Sri Lanka. Here, it is commonly grown in mixed cropping systems, including agroforestry and home gardens. Its tolerance to partial shade makes it suitable for intercropping with coconut, arecanut, and fruit trees (Octavia *et al.* 2024). Global production statistics are limited, as much cultivation occurs in informal or subsistence systems and remains unreported in official databases (FAO, 2011).

2. Arrowroot Production in India

In India, arrowroot is considered a minor tuber crop and remains underutilized despite its nutritional, medicinal, and industrial potential. Cultivation is primarily confined to tropical and subtropical regions, with traditional practices dominating and limited adoption of mechanization or improved varieties (Nair, 1990; Palanisamy *et al.* 2002). Kerala leads in arrowroot cultivation, both as a standalone

crop and intercropped with coconut. Rhizomes are often processed at household or cottage-industry levels for local culinary and medicinal use (George & Mathew, 2004). Tamil Nadu and Odisha also report small-scale cultivation in tribal and rural areas.

3. Role of National Research Institutions

The ICAR–Central Tuber Crops Research Institute (CTCRI), Thiruvananthapuram, has contributed significantly to the documentation of arrowroot agronomy, yield potential, and processing methods. (CTCRI 2018; 2022). Research indicates that improved agronomic practices, such as optimized spacing, organic nutrient management, and proper drainage, can increase yields to 20–35 tonnes/ha, depending on local conditions. Recently, ICAR-CTCRI has released high yielding varieties which shown in Table 1.

4. Regional Production: Maharashtra and Konkan Region

In Maharashtra, arrowroot is not yet a major commercial crop. However, the Konkan region shows promise due to red lateritic to loamy soils, high organic matter, and a humid coastal climate (Government of Maharashtra, 2023; ICAR-CTCRI, 2018). Current cultivation is limited to small region for household and medicinal use, but increasing awareness of arrowroot’s functional starch properties could encourage commercial expansion.

5. Market and Industrial Outlook

Globally, demand for arrowroot starch is rising due to its applications in variety of foods, gluten-

free products, biodegradable packaging, and pharmaceuticals (Market Research Future, 2024). In India, production is largely consumed domestically ($\approx 5,000$ – $6,000$ tonnes annually), with minimal export. Improving farmer-level processing, supply chains, and institutional support could improve commercial prospects (Ravindran *et al.* 2020; Roy *et al.* 2020).

6. Cultivation Requirements of Arrowroot

Arrowroot is well adapted to tropical and subtropical regions, performing best under warm and humid conditions with an optimum temperature range of 20–30 °C. It grows well in well-drained, fertile loamy soils with a slightly acidic pH of 5.5–6.5, while poorly drained and heavy clay soils should be avoided due to the risk of rhizome rot. The crop requires an annual rainfall of about 1000–2000 mm, and supplemental irrigation is necessary during dry periods, particularly during the rhizome bulking stage, as moisture stress at this stage significantly reduces yield. Harvesting is carried out 8–14 months after planting, when the foliage turns yellow and the rhizomes become firm and starch-rich, with fresh rhizome yields ranging from 10 to 20 t ha⁻¹ (Nair, 1990; Palanisamy *et al.* 2002; ICAR–CTCRI, 2018, 2022).

Proximate Composition and Chemical Properties of Arrowroot

The proximate composition of arrowroot (*Maranta arundinacea L.*) reflects its importance as a starch-dominant tuber crop with high digestibility and suitability for specialized dietary applications. Similar to other tropical tubers, arrowroot is characterized

Table 1: Various Arrowroot Varieties suitable for particular states

Variety	Recommended States	Avg. Yield (t/ha)	Starch Yield (t/ha)	Features
Sree Aadya	Kerala	30.04	5.95	High yield, good starch recovery, suitable for humid tropics.
Sree Nakshathra	Chhattisgarh, Jharkhand	32.25	8.59	Best suited for tribal regions; highest starch yield; promotes livelihood improvement.
Sree Karthi	Kerala, Tamil Nadu, Manipur	23.57	5.07	Moderately high yield; broad climatic adaptability.

ICAR-CTCRI, 2024.

by high carbohydrate content, low protein and fat levels, and moderate moisture, which collectively influence its nutritional and functional behaviour in food systems (Nair 1990; Moorthy, 2002).

Fresh arrowroot rhizomes typically contain 65–75% moisture, while processed arrowroot powder exhibits significantly lower moisture levels, usually below 12%, ensuring better shelf stability. The carbohydrate fraction constitutes the major component, accounting for 70–85% (dry basis), predominantly in the form of starch. Protein content in arrowroot is relatively low, generally ranging between 1.5 and 3.5%, while lipid content is negligible (<1%), making arrowroot suitable for low-fat formulations (Sandoval Gordillo *et al.* 2014; Pyasi 2024). Ash content, which reflects the total mineral matter, usually ranges from 0.8 to 2.0%, indicating the presence of essential minerals in small quantities. The low fiber content in refined arrowroot powder enhances digestibility, although whole rhizome flour retains higher dietary fiber levels (Ravindran *et al.* 2020). Table 2 shows the comparison study of proximate composition of arrowroot starch with other tuber starch crops.

1. Chemical Composition and Starch Dominance

The chemical composition of arrowroot is dominated by starch, which contributes to its nutritional value and technological functionality. Arrowroot starch consists primarily of glucose polymers arranged

as amylose and amylopectin. The starch content of mature rhizomes typically ranges from 20 to 25% on a fresh weight basis, increasing substantially after drying and powder preparation (Moorthy 2002; Nogueira *et al.* 2018). Arrowroot starch is noted for its high purity, with minimal contamination by proteins, lipids, or non-starch polysaccharides. This purity contributes to its high paste clarity and neutral taste, making it particularly desirable for infant foods and medical diets. In contrast to cereal starches, arrowroot starch contains very low levels of anti-nutritional factors, further enhancing its digestibility (Hoover 2001).

2. Amylose–Amylopectin Ratio

The amylose content of arrowroot starch typically ranges between 17 and 25%, while amylopectin accounts for 75–83% of the total starch fraction. This amylose–amylopectin balance plays a critical role in determining gelatinization behaviour, paste viscosity, and gel texture. Moderate amylose levels result in soft, elastic gels with reduced retrogradation, which is advantageous in refrigerated and frozen food products (Moorthy 2002; Kaur and Singh 2010).

3. Mineral and Micronutrient Profile

Although arrowroot is not a major source of minerals, it contains trace amounts of potassium, calcium, magnesium, iron, and phosphorus, which contribute

Table 2: Comparison of proximate composition of arrowroot starch with other tuber starch

Component (g/100 g)	Arrowroot	Cassava	Jackfruit Seed	Potato	Corn	References
Moisture	8.0-12.0	8.0-11.0	9.0-12.0	14.0-18.0	10.0-13.0	Malki <i>et al.</i> 2023; Hundekari, 2016
Protein	0.6-0.9	0.3-0.6	0.05 – 0.2	0.1 – 0.3	0.2-0.4	Hoover, 2001; Moorthy, 2002
Lipids	0.2-0.4	0.2-0.5	<0.1	<0.1	<0.1	Singh & Kaur, 2018
Ash	0.9-1.3	0.2-0.4	0.03 – 0.08	0.2 – 0.4	<0.1	CTCRI, 2022; Hundekari, 2016
Crude fibre	0.8-1.2	0.1-0.3	0.1 – 0.3	0.1 – 0.2	0.1 – 0.3	Hoover, 2001; FAO
Total carbohydrates	86.0-90.0	88.0 – 91.0	96.0 – 99.0	96.0 – 99.0	98.0 – 99.5	Sandoval Gordillo <i>et al.</i> 2014
Amylose	22.0-26.0	24.0 – 28.0	28.0 – 34.0	25.0 – 30.0	23.0 – 26.0	Hoover, 2001
Amylopectin	74.0-78.0	72.0 – 76.0	66.0 – 72.0	70.0 – 75.0	74.0 – 77.0	Hoover, 2001
Gelatinization temperature (°C)	66-75	60 – 70	72 – 82	58 – 68	62 – 72	Moorthy, 2002; Kaur <i>et al.</i> 2010
Crystallinity type	B-type	A/B-type	A-type	B-type	A-type	Hoover, 2001

modestly to its nutritional value. Potassium is the most abundant mineral, supporting electrolyte balance and metabolic functions. The mineral profile of arrowroot is influenced by soil type, fertilization practices, and processing methods (Octavia *et al.* 2024).

4. pH and Chemical Stability

Arrowroot starch and powder generally exhibit a neutral to slightly acidic pH (6.0–6.8), which enhances compatibility with a wide range of food systems. The chemical stability of arrowroot starch under mild processing conditions allows its use in heat-treated products such as sauces, custards, and bakery fillings. However, prolonged exposure to high temperatures or acidic environments may lead to partial hydrolysis and viscosity reduction (Singh and Kundu 2016).

Starch Structure, Granule Morphology, and Physicochemical Properties of Arrowroot

Arrowroot starch is characterized by distinct structural and functional features that differentiate it from cereal and other tuber starches. Structurally, the starch consists of amylose and amylopectin arranged in semi-crystalline granules, with molecular organization influencing its hydration, swelling, and pasting behaviour. Microscopic observations have shown that arrowroot starch granules are predominantly oval to elongated in shape with smooth surfaces and well-defined edges, a morphology that contributes to uniform gelatinization and high paste clarity. Rather than theoretical descriptions, recent research findings on the physicochemical and rheological behaviour of arrowroot starch are summarized in Table 3 to provide a concise and comparative overview.

Table 3: Physicochemical and rheological properties of arrowroot starch

Property	Reported range / observation	Measurement conditions	Functional feature	References
Granule size (µm)	15 – 65	SEM / light microscopy	Influences swelling and digestibility	Sandoval Gordillo <i>et al.</i> 2014; Brito <i>et al.</i> 2021
Granule shape	Oval to elongated, smooth surface	SEM	Enhances paste clarity and uniform gelatinization	Singh <i>et al.</i> 2009; Hoover, 2001
Crystalline pattern	B-type	XRD	Associated with higher water uptake and digestibility	Hoover, 2001; Moorthy, 2002
Amylose content (%)	20 – 26	Colorimetric method	Governs gel strength and film-forming ability	Moorthy, 2002; Malki <i>et al.</i> 2023
Gelatinization onset (°C)	66 – 70	DSC	Indicates moderate heat requirement	Hoover, 2001; Kaur <i>et al.</i> 2010
Peak gelatinization (°C)	72 – 76	DSC	Suitable for low-temp. food processing	Moorthy, 2002
Swelling power (g/g)	16 – 19 (at 90 °C)	Hot water method	Improves thickening efficiency	Moorthy, 2002; Nogueira <i>et al.</i> 2018
Solubility (%)	10 – 15 (at 90 °C)	Gravimetric method	Contributes to smooth texture	Kaur <i>et al.</i> 2010
Water absorption capacity	High	Centrifugation method	Useful in sauces and gels	Singh & Kaur, 2018
Pasting behaviour	Pseudoplastic, shear-thinning	RVA / rheometer	Facilitates pumping and mixing	Kim & Yoo, 2009
Peak viscosity (cP)	7,000 – 8,000	RVA	Indicates strong thickening ability	Malki <i>et al.</i> 2023
Retrogradation tendency	Low	Storage studies	Enhances shelf stability	Singh <i>et al.</i> 2016

Arrowroot starch is characterized by predominantly oval to elliptical granules with a moderate size range 15-65 μm , which are generally smaller than potato starch granules (Size range: 15-100 μm) but larger than those of cassava (Size range: 5-35 μm), highlighted in Fig. 2 with distinct morphological features.

1. Gelatinization and Thermal Properties

Gelatinization is a critical physicochemical property that determines the processing behaviour of starch. Arrowroot starch typically gelatinizes at a relatively low temperature range of 70–75°C, which is lower than many cereal starches and comparable to cassava starch. Differential scanning calorimetry (DSC) studies report onset (T_o), peak (T_p), and conclusion (T_c) temperatures indicative of efficient granule hydration and crystalline melting (Kaur and Singh 2010; Nogueira *et al.* 2018).

Low gelatinization temperature offers significant technological advantages, including reduced energy

requirements during cooking and processing. Additionally, arrowroot starch exhibits a narrow gelatinization temperature range, indicating uniform granule structure and consistent thermal behaviour. Fig. 3 shows the temperature of different tuber crops at which starch become viscous forming gel like structure called as gelatinized temperature.

2. Swelling Power and Solubility

Swelling power and solubility are key indicators of starch–water interactions. Arrowroot starch demonstrates high swelling power, particularly at temperatures above gelatinization, due to the disruption of hydrogen bonds within the starch granule. Swelling power values increase progressively with temperature, reflecting the hydration of amorphous regions within the granule (Leach *et al.* 1959; Moorthy, 2002). Solubility of arrowroot starch is generally moderate, increasing with temperature and shear. The balance between swelling and solubility

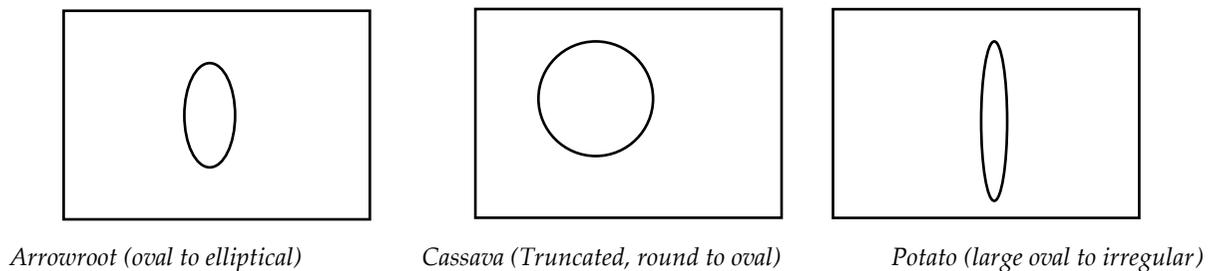


Fig. 2: Comparative morphology diagram of tuber starches granules

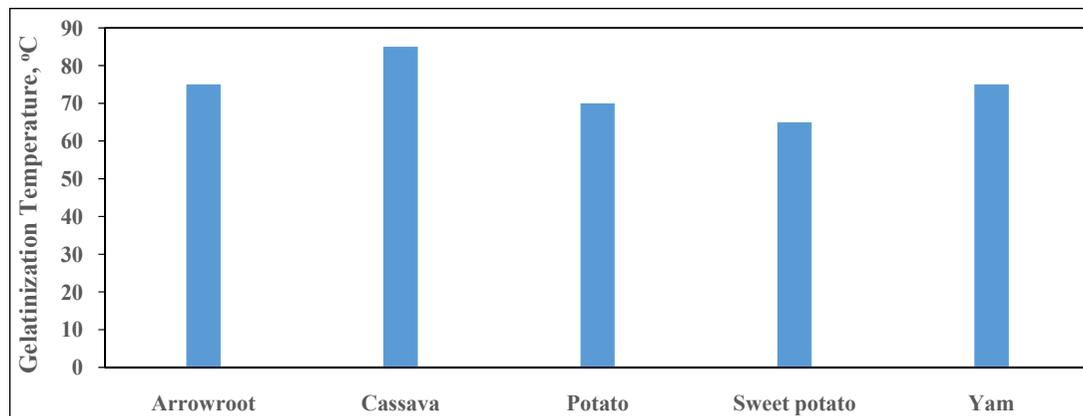
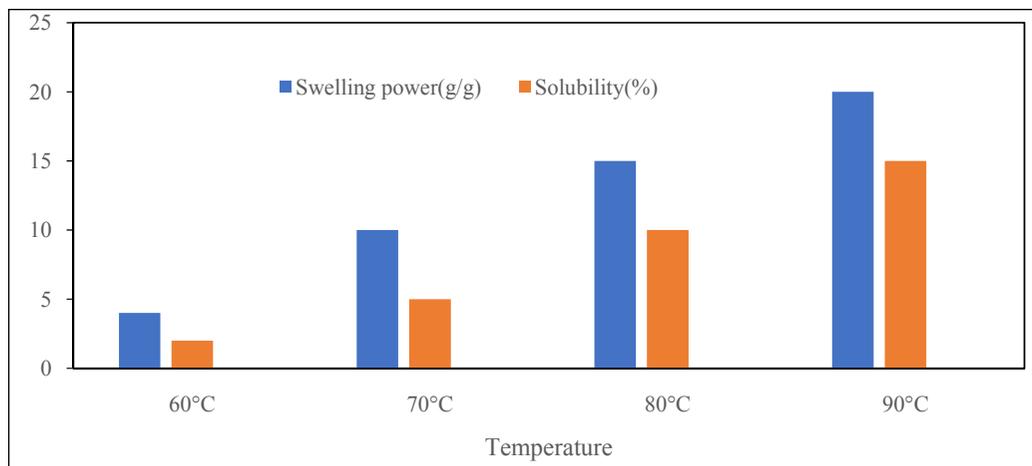


Fig. 3: Gelatinization temperature comparison



Moorthy, 2002; Sandoval Gordillo *et al.*, 2014.

Fig. 4: Swelling power and solubility of arrowroot starch at different temperatures

contributes to the formation of smooth, viscous pastes with minimal granule rupture, which is desirable for thickening and stabilizing food systems. Fig. 4 indicate the ability of swelling and solubility of arrowroot starch at different temperature.

3. Retrogradation and Storage Stability

Retrogradation refers to the reassociation of starch molecules upon cooling and storage, leading to gel hardening and syneresis. Arrowroot starch exhibits lower retrogradation tendency compared to high-amylose starches, owing to its moderate amylose content and B-type crystalline structure. This property enhances its suitability for refrigerated and frozen food products, where textural stability is critical (Moorthy 2002; Singh and Kaur 2018).

Bioactive Compounds, Phytochemicals, and Antioxidant Properties of Arrowroot

The phytochemicals found in arrowroot shows the main groups of bioactive compounds identified using various analytical methods. Different plant part reported chemicals which highlighted the medicinal and antioxidant properties. This summary helps in understanding the chemical diversity of arrowroot. Table 4 shows the structural representation of phytochemicals reported in arrowroot.

1. Phenolic Compounds and Antioxidant Potential

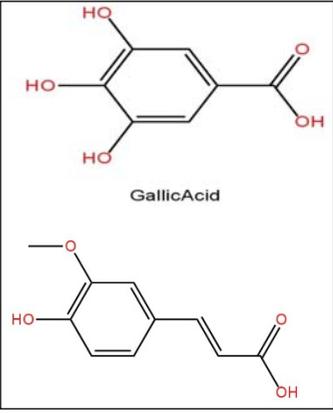
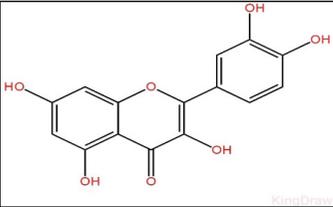
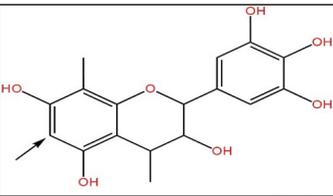
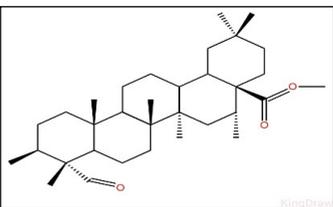
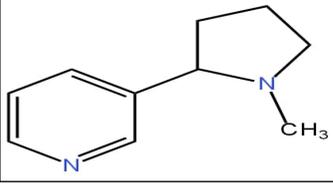
Phenolic compounds constitute the most extensively investigated phytochemicals in arrowroot. Measurements of total phenolic content have confirmed the presence of measurable phenolics that contribute to the antioxidant capacity of the tuber. Studies comparing cultivation systems have shown that arrowroot grown under agroforestry conditions tends to accumulate higher phenolic levels than crops grown in open fields, possibly due to increased environmental stress and shading effects that stimulate secondary metabolite synthesis (Octavia *et al.* 2024).

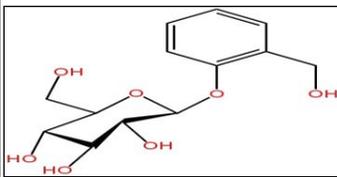
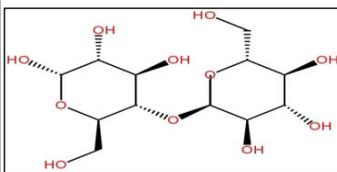
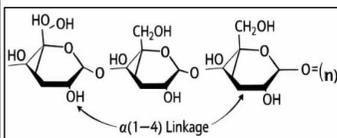
Antioxidant activity assessed through in vitro assays such as DPPH and FRAP indicates moderate free radical scavenging capacity in arrowroot extracts. While the antioxidant activity is lower than that of highly pigmented fruits, it remains nutritionally relevant, particularly when arrowroot is consumed regularly or incorporated into functional food formulations (Malki *et al.* 2023).

2. Flavonoids and Related Phytochemicals

In addition to phenolic compounds, arrowroot tubers contain low levels of flavonoids and related phytochemicals. Despite their limited concentration, these compounds contribute synergistically to

Table 4: Phytochemicals Reported in Arrowroot (*Maranta arundinacea L.*) and Their Structural Classes

Phytochemical Group	Representative Compounds	Structural presentation	Basic Structural Features	Plant Part / Extract	Reported Biological Relevance	References
Phenolic acids	Gallic acid, Ferulic acid, p-Coumaric acid	 <p>Gallic acid</p> <p>Ferulic acid</p>	Aromatic benzene ring with one or more hydroxyl (-OH) groups and a carboxylic acid side chain	Rhizome, starch extract	Antioxidant, free-radical scavenging	Malki <i>et al.</i> 2023; Roy <i>et al.</i> 2020
Flavonoids	Quercetin, Kaempferol (trace levels)	 <p>Quercetin</p>	Polyphenolic structure with two aromatic rings (A & B) linked by a heterocyclic ring (C6-C3-C6)	Rhizome powder	Antioxidant, anti-inflammatory	Singh <i>et al.</i> 2016; Brito <i>et al.</i> 2021
Tannins	Condensed tannins	 <p>Condensed tannins</p>	High-molecular-weight polyphenols with multiple hydroxyl groups	Rhizome extract	Antimicrobial, antioxidant	Nair, 1990; Malki <i>et al.</i> 2023
Saponins	Steroidal/triterpenoid saponins (low levels)	 <p>Saponin</p>	Glycosidic structure consisting of a hydrophobic aglycone linked to sugar moieties	Rhizome	Immunomodulatory, antimicrobial	Palanisamy <i>et al.</i> 2002; Roy <i>et al.</i> 2020
Alkaloids	Trace alkaloidal compounds	 <p>Alkaloids</p>	Nitrogen-containing heterocyclic structures	Rhizome	Minor physiological activity	Nair, 1990

Glycosides	Phenolic glycosides		Phenolic aglycone bound to sugar units via glycosidic linkage	Rhizome	Antioxidant potential	Singh & Kaur, 2018
Polysaccharides (non-starch)	Soluble dietary fibers	 Starch soluble	Long-chain carbohydrate polymers	Rhizome	Prebiotic, gut health	Moorthy, 2002; ICAR-CTCRI, 2022
Starch-derived bioactive fractions	Resistant starch fractions	 $\alpha(1-4)$ Linkage	α -D-glucose polymers with limited enzymatic digestibility	Starch	Low glycemic response, gut health	Hoover, 2001; Malki <i>et al.</i> 2023

the overall antioxidant and protective effects of arrowroot. The presence of flavonoids supports traditional uses of arrowroot in managing mild digestive discomfort and inflammatory conditions, as documented in ethnobotanical and folk medicine practices (Posey, 1985; Pyasi, 2024).

3. Immunomodulatory Properties

Emerging research has revealed that arrowroot may possess immunomodulatory properties, particularly associated with its starch fraction. Experimental studies using *in vitro* cell culture models have shown that thermally processed arrowroot starch extracts can enhance immunoglobulin production, including IgM, in human immune-related cell lines. These findings suggest that heat-induced modification of starch polysaccharides may generate biologically active structures capable of stimulating immune responses (ICAR-CTCRI Press Release, 2024).

4. Effect of Processing on Bioactive Components

Processing techniques such as boiling, drying, and starch extraction influence the stability and activity of bioactive compounds in arrowroot. Thermal treatments may lead to partial loss of heat-sensitive phenolics; however, they can also enhance biological

functionality by altering polysaccharide structures and improving bioavailability. Therefore, careful optimization of processing conditions is essential to preserve or enhance the health-promoting properties of arrowroot-based products (Sharma & Patel, 2021). Table 5 shows the characteristics of Arrowroot starch.

Dietary Fiber and Digestive Health Attributes of Arrowroot

1. Dietary Fiber Content in Arrowroot

Arrowroot (*Maranta arundinacea* L.) is generally considered a low-fiber tuber crop when processed into refined starch or powder; however, the whole rhizome flour retains measurable amounts of dietary fiber that contribute to digestive health. The dietary fiber content of arrowroot varies depending on processing intensity, with higher levels observed in minimally processed flours compared to purified starch (Nair 1990; Ravindran *et al.* 2020). Dietary fiber in arrowroot consists of both soluble and insoluble fractions, though insoluble fiber predominates. The removal of fibrous material during starch extraction explains the lower fiber levels in commercial arrowroot starch, which enhances digestibility but reduces fiber-associated physiological benefits.

Table 5: Characteristics of Arrowroot (*Maranta arundinacea L.*) Starch

Sl. No.	Research Focus	Key Findings	Significance / Remarks	Author(s) & Year
1	Physicochemical and functional properties of tropical tuber starches	Arrowroot starch showed low gelatinization temperature, high paste clarity, and good digestibility	Arrowroot starch showed low gelatinization temperature, high paste clarity, and good digestibility	Moorthy (2002)
2	Structural and physicochemical comparison of tuber starches	Arrowroot starch exhibited B-type crystallinity and low retrogradation tendency	Highlighted advantages over cereal starches for food and biomedical uses	Hoover (2001)
3	Granule morphology, rheology, and digestibility	Oval to elongated granules (15–50 μm); pseudoplastic and shear-thinning behaviour	Important for processing, pumping, and formulation stability	Kaur <i>et al.</i> (2010)
4	Microscopic and structural characterization	Dense starch granule packing within rhizome parenchyma	Explained high starch recovery efficiency	Sandoval Gordillo <i>et al.</i> (2014)
5	Functional and pasting properties	High water absorption, swelling power, and paste stability	Confirmed suitability for thickening and stabilizing applications	Nogueira <i>et al.</i> (2018)
6	Thermal and rheological behaviour	Arrowroot starch formed stable gels with soft texture	Useful in sauces, desserts, and dairy products	Singh <i>et al.</i> (2016)
7	Nutritional and functional evaluation	Arrowroot starch showed low glycemic response and good digestibility	Supported use in functional and clinical nutrition	Roy <i>et al.</i> (2020)
8	Development of starch-based films	Arrowroot starch demonstrated good film-forming ability with plasticizers	Basis for biodegradable and edible packaging	Souza <i>et al.</i> (2013)
9	Mechanical and barrier properties of starch films	Plasticized arrowroot films had improved flexibility and oxygen barrier properties	Potential replacement for synthetic packaging materials	Soares <i>et al.</i> (2021)
10	Pharmaceutical applications of starches	Arrowroot starch suitable as tablet binder and disintegrant	Highlighted non-food industrial applications	Singh & Kaur (2018)
11	Nutritional and medicinal properties	Arrowroot starch suitable as tablet binder and disintegrant	Validated traditional medicinal claims	Malki <i>et al.</i> (2023)
12	Effect of thermal processing on bioactivity	Heat-treated arrowroot starch enhanced IgM production in immune cells	Indicated emerging immunomodulatory potential	ICAR-CTCRI (2024)

2. Role of Dietary Fiber in Digestive Health

Dietary fiber plays a crucial role in maintaining gastrointestinal health by promoting regular bowel movements, enhancing gut motility, and supporting a healthy intestinal environment. The insoluble fiber fraction in arrowroot contributes to fecal

bulk, while the soluble fraction may aid in slowing gastric emptying and improving nutrient absorption (Narasinga Rao and Narayana 1982).

Arrowroot has traditionally been used as a soothing food for the digestive system, particularly in cases of diarrhea, dysentery, and gastrointestinal irritation. Its

mild nature and easy digestibility make it suitable for infants, elderly individuals, and patients recovering from illness (Posey 1985; Pyasi 2024).

3. Arrowroot as a Prebiotic-Friendly Ingredient

Although arrowroot is not a major source of resistant starch, partial gelatinization and retrogradation during cooling may generate small amounts of resistant starch, which can act as a substrate for beneficial gut microbiota. These fermentable fractions may support short-chain fatty acid production in the colon, contributing to gut health and metabolic regulation (Singh and Kaur 2018).

4. Dietary Applications Related to Digestive Health

Due to its gentle digestive profile, arrowroot is widely incorporated into: Infant foods and weaning formulations; Convalescent and clinical diets; Low-residue and soft-texture foods

Traditional medicinal preparations; Its ability to provide energy without imposing digestive stress makes arrowroot an ideal carbohydrate source for nutritionally vulnerable populations (George and Mathew 2004).

Health Benefits of Arrowroot with Special Emphasis on Gluten-Free and Low Glycemic Index Properties

1. Gluten-Free Nature and Its Nutritional Significance

Arrowroot (*Maranta arundinacea* L.) is naturally gluten-free, as it is derived from a tuber rather than cereal grains. This characteristic makes arrowroot an important dietary ingredient for individuals with celiac disease, non-celiac gluten sensitivity, and wheat allergies. Unlike gluten-containing flours, arrowroot starch does not trigger inflammatory or autoimmune responses associated with gluten intolerance, thereby providing a safe alternative carbohydrate source (Singh and Kaur 2018; Pyasi 2024). The gluten-free nature of arrowroot has led to its increasing incorporation into specialized food products such as gluten-free bakery items, infant foods, and nutritionally sensitive formulations. Additionally, its neutral taste and excellent thickening ability enhance

product quality without compromising sensory attributes.

2. Low Glycemic Index and Blood Glucose Regulation

Arrowroot is characterized by a low to moderate glycemic index (GI), which is attributed to its starch composition, granular structure, and high digestibility without rapid glucose release. The presence of B-type crystalline starch and moderate amylose content contributes to slower enzymatic breakdown, resulting in a gradual increase in blood glucose levels (Hoover 2001; Moorthy 2002).

This property makes arrowroot suitable for individuals managing diabetes mellitus, insulin resistance, and metabolic disorders. Traditional dietary practices have long recommended arrowroot-based foods for convalescent patients and individuals requiring easily digestible, low-GI carbohydrate sources.

3. Digestive Tolerance and Therapeutic Uses

Arrowroot is widely recognized for its soothing effect on the gastrointestinal tract. Its easy digestibility, low fiber residue (in refined starch), and absence of irritant compounds make it suitable for individuals with digestive disorders such as diarrhea, gastritis, and irritable bowel conditions (Posey 1985; George and Mathew 2004). In traditional medicine systems across India, Sri Lanka, and the Caribbean, arrowroot preparations have been used to relieve digestive discomfort, restore energy during illness, and support recovery in malnourished populations.

4. Immunomodulatory and Anti-Inflammatory Potential

Emerging research has revealed that arrowroot may exert immunomodulatory effects, particularly when starch is subjected to controlled thermal processing. Laboratory studies have shown increased production of immunoglobulin M (IgM) in human cell models treated with heat-processed arrowroot extracts, suggesting stimulation of innate immune responses (ICAR-CTCRI Press Release 2024). In addition, the presence of phenolic compounds and flavonoids

contributes to mild anti-inflammatory and antioxidant effects, which may help mitigate oxidative stress and support immune health. Although these findings are preliminary, they provide scientific support for the traditional use of arrowroot in therapeutic diets.

Applications of Arrowroot Starch and Powder in Food and Non-Food Industries

1. Food Applications of Arrowroot Starch

In recent years, arrowroot starch has gained renewed attention in the food industry due to growing consumer demand for clean-label, gluten-free, and plant-based ingredients. Its neutral flavour, high paste clarity, and excellent thickening ability make it suitable for a wide range of food applications, particularly where smooth texture and digestibility are required (Nogueira *et al.* 2018; Pyasi 2024).

Arrowroot starch is widely used as a thickening and stabilizing agent in products such as soups, sauces, gravies, puddings, custards, and fruit-based desserts. Compared to cereal starches, arrowroot provides superior clarity and a glossy appearance, which enhances the sensory appeal of translucent food systems. Its low gelatinization temperature further reduces thermal stress during processing, making it advantageous for heat-sensitive formulations (Sandoval Gordillo *et al.* 2014).

Recent studies have also explored the use of arrowroot starch in bakery and confectionery products, particularly gluten-free cakes and biscuits. The starch contributes to improved crumb softness, moisture retention, and structural integrity in the absence of gluten (Roy *et al.* 2020; Singh and Kaur 2018).

2. Infant Foods and Clinical Nutrition

Arrowroot starch has long been incorporated into infant and convalescent foods, owing to its high digestibility and hypoallergenic nature. Contemporary research continues to support its suitability for clinical nutrition, especially for individuals with compromised digestive function. Its smooth gel formation and low residue reduce

gastrointestinal stress and enhance nutrient absorption (George and Mathew 2004; Pyasi 2024). Recent interest in low-glycemic and functional infant foods has further positioned arrowroot as a valuable ingredient in nutritionally sensitive formulations, particularly in regions where traditional foods remain integral to infant feeding practices.

3. Arrowroot Starch in Edible Films and Biodegradable Packaging

One of the most rapidly expanding application areas of arrowroot starch in recent literature is its use in biodegradable and edible films, driven by global efforts to reduce petroleum-based plastic waste. Arrowroot starch exhibits excellent film-forming capacity, transparency, and oxygen barrier properties, making it a promising alternative to conventional synthetic polymers (Abdillah and Charles 2021; Oliveira Filho *et al.* 2021).

Recent studies (2021–2023) have demonstrated that arrowroot starch-based films, when plasticized with glycerol or sorbitol, exhibit improved flexibility and tensile strength. The incorporation of natural additives such as plant extracts, essential oils, and agro-industrial byproducts has further enhanced antioxidant and antimicrobial properties, extending the shelf-life of packaged foods (Malki *et al.* 2023; Ferreira *et al.* 2022).

4. Pharmaceutical and Biomedical Applications

Arrowroot starch has also attracted interest in the pharmaceutical industry, where it is used as a binder, disintegrant, and filler in tablet formulations. Its non-toxic, non-irritant, and biodegradable properties make it suitable for oral drug delivery systems. Recent research highlights its compatibility with active pharmaceutical ingredients and its potential use in controlled-release formulations (Singh and Kaur 2018; Sharma and Patel 2021). Additionally, the smooth texture and hypoallergenic nature of arrowroot starch have supported its use in cosmetic and personal care products, including powders, creams, and skin-soothing formulations.

5. Emerging Non-Food Applications

Recent application of Arrowroot starch studies shown in Table 6, which have explored arrowroot starch in biopolymer composites and thermoplastic starch materials, where it serves as a renewable matrix material reinforced with natural fibers. Such composites exhibit improved biodegradability and mechanical performance, offering sustainable alternatives for packaging, agricultural films, and disposable materials (Tarique *et al.* 2022).

The increasing focus on circular bioeconomy concepts has positioned arrowroot starch as a high-value bioresource, particularly when derived from underutilized or regionally adapted tuber crops.

Value-Added Products and from Arrowroot

Arrowroot starch is valued in food formulations due to its high digestibility, neutral flavour, low gelatinization temperature, and excellent paste clarity. Unlike cereal starches, it produces smooth and translucent gels, making it suitable for delicate food systems such as infant foods and desserts (Moorthy, 2002; Hoover, 2001). Its gluten-free nature and low glycemic response further enhance its importance in functional and clinical nutrition (Roy *et al.* 2020; Malki *et al.* 2023). Table 7 shows the various food products prepared from Arrowroot powder and starch.

Table 6: Recent applications of arrowroot starch

Application area	Key findings	Reference
Edible films	Improved barrier & antioxidant properties	Abdillah & Charles 2021
Active packaging	Enhanced shelf life with plant extracts	Oliveira Filho <i>et al.</i> 2021
Biodegradable films	Improved flexibility with emulsifiers	Ferreira <i>et al.</i> 2022
Functional foods	Low GI, gluten-free formulations	Pyasi 2024
Biopolymer composites	Sustainable thermoplastic materials	Tarique <i>et al.</i> 2022

Table 7: Food Products Prepared from Arrowroot Powder and Starch

Product Category	Food Products	Base Material	Key Features / Functional Role	Reference
Thickened foods	Sauces, gravies, soups, fruit fillings	Starch	Forms clear and glossy pastes; neutral taste; stable under acidic conditions	Moorthy (2002); Singh <i>et al.</i> (2016)
Desserts	Puddings, custards, jellies	Starch	Smooth texture, high paste clarity, low gelatinization temperature	Hoover (2001); Kaur <i>et al.</i> (2010)
Gluten-free bakery products	Cakes, cookies, biscuits, bread	Powder / starch	Improves structure, moisture retention, and softness in gluten-free systems	Nogueira <i>et al.</i> (2018); Singh <i>et al.</i> (2016)
Infant foods	Weaning foods, porridge, pap Powder	Powder	Easily digestible starch; suitable for infants and elderly	Moorthy (2002); Nair (1990)
Dairy products	Yogurt, ice cream	Starch	Prevents syneresis; improves viscosity and mouthfeel	Kaur <i>et al.</i> (2010); Hoover (2001)
Meat and savory products	Sausages, patties, batters	Starch	Acts as binder and moisture retainer; improves texture	Singh & Kaur (2018)
Traditional foods	Arrowroot biscuits, indigenous porridges	Powder	Cultural importance; simple processing	Purseglove (1985); George & Mathew (2004)

Functional foods	Health drinks, dietary supplements	Powder / modified starch	Gluten-free, low glycemic response, digestive benefits	Malki <i>et al.</i> (2023); Roy <i>et al.</i> (2020)
Edible coatings	Coatings for fruits and fried foods	Starch	Film-forming ability; reduces oil uptake	Souza <i>et al.</i> (2013); Soares <i>et al.</i> (2021)

CONCLUSION

Arrowroot (*Maranta arundinacea* L.) is a nutritionally valuable yet underutilized tuber crop with considerable potential in food, health, and industrial applications. This review highlights its botanical features, production status, nutritional composition, starch characteristics, bioactive compounds, and versatile applications. Despite its historical importance, arrowroot remains marginal in commercial agriculture compared with other tropical tuber crops such as cassava and potato.

Nutritionally, arrowroot is distinguished by its highly digestible starch, gluten-free nature, and low glycemic index, making it suitable for infants, elderly individuals, and populations with dietary sensitivities. The physicochemical properties of arrowroot starch including B-type crystallinity, low gelatinization temperature, high paste clarity, and reduced retrogradation underpin its utility in diverse food systems, pharmaceuticals, and biodegradable materials.

Recent studies have expanded the understanding of arrowroot beyond its carbohydrate content, demonstrating bioactive compounds, moderate antioxidant activity, and emerging immunomodulatory effects. These findings support its traditional medicinal use and reinforce its potential as an ingredient in functional foods and clinical nutrition. Furthermore, advances in starch modification and film-forming technologies demonstrate arrowroot starch's feasibility as a sustainable alternative to petroleum-based polymers in edible films and biodegradable packaging.

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