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RESEARCH PAPER

Studies on Physiochemical, Functional, and Rheological Properties of Arrowroot Starch

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ABSTRACT

Physicochemical, functional, and rheological properties of arrowroot (*Maranta arundinacea L*) starch were investigated to evaluate its suitability for food and industrial applications. The starch exhibited low ash content (1.10–1.21%), near-neutral pH (7.5–7.6), and moisture content within safe limits (~12%), indicating good purity and storage stability. Functional properties revealed high water absorption capacity (1.6–1.7 g/g), swelling power (11–12 g/g), and solubility (12%), highlighting its strong hydration and thickening potential. The gelatinization temperature was observed in the moderate range (72–73°C), suggesting ease of thermal processing. Rheological properties of gelatinized arrowroot starch dispersions at different concentrations (5%, 10%, 15%, 20% and 25% w/v) were determined using a Brookfield viscometer over a wide range of shear rates. The dispersions exhibited shear-thinning behaviour and showed non-Newtonian, pseudoplastic flow characteristics ($n < 1$). The Herschel–Bulkley model adequately described the flow behaviour with a high coefficient of determination ($r^2 \geq 0.98$), and the model parameters were strongly dependent on starch concentration. Overall, the combined physicochemical, functional, and rheological characteristics indicate that arrowroot starch can serve as an effective natural thickener, stabilizer, and biodegradable material for diverse applications.

Keywords: Arrowroot starch, Physicochemical, Gelatinization temperature, rheology, Herschel–Bulkley

Starch is one of the most widely utilized natural biopolymers due to its abundance, biodegradability, and versatile functional properties in food as well as non-food industries. In recent years, there has been growing interest in identifying alternative and underutilized starch sources that can serve as sustainable substitutes for conventional starches such as corn, potato, and cassava Singh *et al.* (2018); Hoover, (2001). Among these, arrowroot (*Maranta arundinacea L.*), a tropical tuber crop belonging to the family *Marantaceae*, has gained renewed attention owing to its unique physicochemical and functional characteristics Kaur *et al.* (2010), Vekhande and Swami, (2025).

Arrowroot is considered one of the earliest known sources of starch and has traditionally been valued for its high digestibility and nutritional benefits. The plant develops underground rhizomes that serve as storage organs rich in starch reserves Moorthy, (2002). It is believed to have originated in the tropical regions of Central and South America and subsequently spread to Asia and Africa, where it adapted to a wide range of Agro-climatic conditions Coelho *et al.* (2005). Despite its wide distribution, arrowroot continues to

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be cultivated on a limited scale and is often regarded as a minor crop, particularly in countries like India where its cultivation is largely confined to regions such as Kerala, Tamil Nadu, and Odisha Singh and Kundu, (2016). However, regions like the Konkan belt have been identified as suitable for its expansion due to favourable soil and climatic conditions ICAR-CTCRI, (2018).

From a nutritional standpoint, arrowroot starch is characterized by high carbohydrate content, low levels of protein and fat, and a gluten-free nature, making it suitable for individuals with celiac disease and other dietary restrictions. Malki *et al.* (2023). Additionally, its low glycemic response enhances its applicability in diabetic-friendly diets. The starch is also known for its high digestibility and smooth texture, which supports its use in infant foods and specialized dietary formulations Singh *et al.* (2016), Vekhande and Swami, (2025).

The functional performance of starch in industrial applications is primarily governed by its physicochemical properties, including moisture content, granule size, swelling behaviour, solubility, and thermal characteristics. Arrowroot starch typically consists of oval to elongated granules with smooth surfaces and exhibits B-type crystallinity, which significantly influences its swelling capacity, gelatinization behaviour, and digestibility Kaur *et al.* (2010). Its relatively low gelatinization temperature (70–75°C), high swelling power, and good water-holding capacity make it suitable for use as a thickening, stabilizing, and gelling agent in various food systems Singh *et al.* (2016).

The amylose content of arrowroot starch generally ranges from 17 to 23%, which contributes to the formation of soft gels and reduced retrogradation compared to other starches such as corn and potato Moorthy, (2002). These characteristics are advantageous for improving texture and stability in food products. Furthermore, the reduced tendency for retrogradation enhances its suitability for both food and pharmaceutical applications, where stability during storage is critical Hoover, (2001).

In addition to conventional food uses, arrowroot starch has gained attention in emerging applications such as biodegradable films and edible coatings. Its natural film-forming ability, transparency, and relatively low oxygen permeability make it a promising material for sustainable packaging systems Souza *et al.* (2013); Soares *et al.* (2021). However, similar to other starch-based films, arrowroot starch films exhibit brittleness, which can be improved by incorporating plasticizers such as glycerol or sorbitol to enhance flexibility and mechanical strength Abdillah and Charles, (2021).

Rheological properties play a crucial role in determining the behaviour of starch during processing and application. Arrowroot starch pastes typically exhibit non-Newtonian, shear-thinning (pseudoplastic) behaviour, which facilitates ease of mixing, pumping, and handling in industrial processes Kaur *et al.* (2010). Understanding these flow characteristics is essential for optimizing its application in food formulations, coatings, and biodegradable materials. Although extensive research has been conducted on common starch sources, comprehensive studies on the physicochemical and functional properties of arrowroot starch remain relatively limited. Therefore, a systematic evaluation of these properties is essential to establish its potential as an alternative industrial starch source.

In this context, the present study aims to investigate the physicochemical, functional, and rheological properties of arrowroot starch. The findings are expected to provide valuable insights into its structural and functional behaviour, thereby supporting its application in food systems, pharmaceutical formulations, and biodegradable material development.

MATERIALS AND METHODS

Raw Materials

Fresh rhizomes of arrowroot (*Maranta arundinacea* L.), Trivandrum variety, were procured from the University Farm, Central Research Station, Wakawali, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Maharashtra, India. This variety is recognized for its

comparatively higher rhizome yield (30–35 t ha^{-1}) and starch recovery potential (20–25%) under favourable agro-climatic conditions. The harvested rhizomes were carefully sorted cleaned thoroughly in tap water to remove any dirt, dust, adhered on its surface. to ensure uniformity in quality and composition of the extracted starch.

Extraction of Arrowroot Starch

Fig. 1 shows the process flow chart for the extraction of Arrowroot starch. The starch was extracted as per the procedure of Cruz and Dash (2004). The disease-free fresh Arrowroot rhizomes were washed in tap water to remove its adhered dirt and dust. The rhizomes were peeled manually and sliced with knife to approximate 3 mm thicker and crushed in mixture grinder and mixed with deionised water in 1:2 ratio to form a slurry. The mixture was allowed to settle for 15 minutes then the mixture was filtered using Muslin cloth to remove the fibres. The filtration was allowed to settle using natural sedimentation process for 12 hours. After the removal of supernatant water the starch sediments were collected separately and dried at 50°C for 6 hours. The dried mass were grounded in mixture to break down particles and then starch material were packed in polythene bags.

Selection of Fresh and Disease-free Rhizomes
↓
Washing
(Removal of soil and impurities using distilled water)
↓
Peeling
(Removal of outer skin manually)
↓
Slicing
(Cutting into ~3 mm thickness)
↓
Crushing / Blending
(With deionized water in 1:2 ratio)
↓
Slurry Formation
↓
Filtration
(Through muslin cloth to remove fiber)
↓
Filtrate Collection
↓
Sedimentation
(Allow to stand for ~12 hours)
↓
Decantation
(Removal of supernatant water)
↓
Starch Sediment Collection
↓
Drying
(Oven drying at 60°C for 4 hours)
↓
Grinding (if required)
↓
Arrowroot Starch Powder
↓
Packaging & Storage
(Airtight polyethylene bags)

Fig. 1: Process flow chart for Extraction of Arrowroot starch

Cruz and Dash (2004)

Determination of Physicochemical Properties of Arrowroot Strach

1. Ash Content

Ash content, representing the total mineral residue of Arrowroot starch, was determined according to the standard method prescribed by AOAC (2005). Approximately 5 g of the dried starch sample was accurately weighed into a pre-weighed silica crucible. The sample was subjected in a muffle furnace maintained at 550 ± 25°C for a duration of 5–6 hours until complete oxidation of organic matter was achieved.

The crucible was then transferred to a desiccator to cool to room temperature and subsequently weighed. The experiment was conducted in triplicate, and the mean value was reported.

The ash content was calculated using the following expression:

$$\% \text{ of ash in sample} = \frac{W_3 - W_1}{W_2 - W_1} \times 100 \quad \ldots (1)$$

Where:

W_1 = Weight of empty crucible (g)

W_2 = Weight of crucible + sample before taking ash (g)

W_3 = Weight of crucible + ash (g)

2. pH Measurement

The pH of the arrowroot starch was determined following AOAC (2014) procedures with minor modifications. A suspension was prepared by dispersing 5 g of starch in 20 mL of distilled water. The mixture was stirred continuously for 5 minutes to ensure uniform dispersion and allowed to equilibrate for 10 minutes to achieve partial sedimentation.

The pH of the supernatant liquid was measured using a calibrated digital pH meter at room temperature. Calibration of the instrument was performed using standard buffer solutions (pH 4.0 and 7.0) prior to measurement to ensure accuracy. All measurements were carried out in triplicate, and the average value was recorded.

3. Bulk Density

Bulk density was determined using the tapping method described by Peroni *et al.* (2006) Narayana and Narasinga Rao (1982). A known quantity of starch was gradually introduced into a graduated measuring cylinder without compaction. The cylinder was then tapped gently on a flat surface until no further reduction in volume was observed.

The bulk density was calculated using:

$$\text{Bulk Density (g/cm}^3) = \frac{W}{V} \quad \ldots (2)$$

Where:

W = Mass of starch sample (g)

V = Final settled volume (cm^3)

Bulk density provides insight into the packing characteristics and flow behaviour of powdered materials, which are important in processing and storage operations. Experiment conducted trice for accuracy.

4. Particle Size Distribution

Particle size distribution of arrowroot starch was determined using mechanical sieve analysis as described by sajeev *et al.* (2012) A known mass of dried starch sample was placed on the top sieve of a stacked set of standard sieves arranged in descending order of aperture size. The sieve assembly was subjected to mechanical shaking for a period of 10–15 minutes to facilitate separation of particles based on size. The quantity of starch retained on each sieve was carefully collected and weighed.

The percentage of material retained on each sieve was calculated as:

$$\% \text{ Retained} = \frac{W_r}{W} \times 100 \quad \ldots (3)$$

Where:

W_r = Weight retained on sieve (g)

W = Total weight of sample (g)

Cumulative particle size distribution was used to estimate the mean particle diameter. All measurements were carried out in triplicate, and the average value was recorded.

5. Moisture Content

Moisture content was determined using the hot air oven method (AOAC, 2010). Approximately 5 g of starch sample was placed in a pre-weighed moisture dish and dried in an oven at 105 ± 1°C until a constant weight was achieved. Sample was cooled in desiccator after drying. Moisture was calculated by using formula:

$$\text{Moisture content(db)} = \frac{W_m}{W_d} \times 100 \quad \ldots (4)$$

Where:

W_m = Initial weight of sample (g)

W_d = Final dry weight (g)

The experiment was conducted in three times and take average reading as a finial value.

6. Gelatinization Temperature

Gelatinization temperature was determined following the method described by Akpa *et al.* (2012). A starch suspension was prepared by mixing 1.5 g of starch with 10 mL distilled water. The suspension was heated gradually in a thermostatically controlled water bath while continuously monitoring the temperature.

The temperature at which the suspension exhibited noticeable thickening and loss of translucency was recorded as the gelatinization temperature. Experiment conducted trice for accuracy.

Functional Properties of Arrowroot strach

1. Water Absorption Capacity (WAC)

Water absorption capacity was determined using the method of Roy *et al.* (2020). One gram of starch was mixed with 10 mL of distilled water and agitated for uniform dispersion. The mixture was centrifuged at 2000 rpm for 12 minutes, and the supernatant was decanted. Water Absorption Capacity was determined by using:

$$WAC \text{ (g/g)} = \frac{\text{Volume of water absorbed}}{\text{Weight of dry sample}} \times 100 \quad \ldots (5)$$

This process was conducted triplicate and mean value was taken for accuracy.

2. Swelling Power and Solubility

Swelling power and solubility of arrowroot starch were determined following the method of Oliveira *et al.* (2021) with slight modifications. Approximately 1 g of starch sample (dry basis) was suspended in 10 mL of distilled water and heated at 85°C for 30 minutes with intermittent stirring. The samples were then cooled to room temperature and centrifuged at 3000 rpm for 15 minutes.

The supernatant was carefully decanted and dried to constant weight to determine solubility, while the sediment was weighed to determine swelling power.

$$\text{Swelling Power (g/g)} = \frac{W}{W_d} \quad \ldots (6)$$

$$\text{Solubility} = \frac{W_{sup}}{W_d} \times 100 \quad \ldots (7)$$

Where:

W = Weight of sediment (g)

W_{sub} = Weight of Supernatant (g)

W_d = Weight of dry sample (g)

All determinations were carried out in triplicate, and mean values were reported.

3. Swelling Volume

Swelling volume was determined using the method of Hirsch and Kokini (2002). About 0.2 g of starch sample was mixed with 5 mL distilled water and heated at 95°C for 60 minutes. The samples were then cooled and centrifuged at 1000 rpm for 30 minutes.

The volume of the swollen sediment was recorded and expressed as swelling volume:

$$\text{Swelling volume (mL/g)} = \frac{V}{W} \quad \ldots (8)$$

Where:

V = Volume of swollen sediment (mL)

W = Weight of sample (g)

The analysis was performed in triplicate, and average values were calculated.

Rheological analysis of Gelatinized Starch Dispersions

1. Preparation of Gelatinized Starch Dispersions

Starch dispersions of varying concentrations (5%,

10%, 15%, 20%, and 25% w/v) were prepared by dispersing the required amount of starch in 100 mL distilled water. The suspensions were heated in a water bath at 90 ± 2°C for 20 minutes with continuous stirring until complete gelatinization occurred Hundekari and Swami, (2024). The dispersions were further maintained for 5 minutes at the same temperature and then cooled to about 50°C before analysis.

All samples were prepared in triplicate to ensure reproducibility.

2. Apparent Viscosity Measurement

The apparent viscosity of gelatinized arrowroot starch dispersions was measured using a Brookfield Viscometer (Model DV-II+ Pro, Brookfield Engineering Laboratories, USA). The instrument was calibrated prior to measurement, and all readings were taken at a controlled temperature of 25 ± 1°C. The gelatinized starch dispersion was transferred into a 500 mL beaker, and the spindle (No. 07) was immersed up to the designated mark. Viscosity measurements were recorded at varying rotational speeds ranging from 0.3, 0.6, 1.5, 2.5, 4, 6, 10, 12, 20, 30, 50, 60 and 100 rpm.

The apparent viscosity (η_a) obtained from the instrument was expressed in centipoise (cP) and converted into Pascal-seconds (Pa·s) using:

$$Pa{\cdot}s = cP \times 0.001 \quad \ldots (9)$$

3. Determination of Shear Rate (γ)

For rotational viscometers, shear rate is related to the angular velocity of the spindle. The average shear rate was calculated using the following expression (Razavi *et al.* 2007):

$$\gamma = \frac{8}{\pi} \times \Omega \quad \ldots (10)$$

Where:

γ = Shear rate (s^{-1})

Ω = Angular velocity (rad/s)

Angular velocity was calculated from rotational speed (N, rpm):

$$\Omega = \frac{2\pi N}{60} \quad \ldots (11)$$

Thus, combining:

$$\gamma = \frac{8}{\pi} \times \frac{2\pi N}{60}$$

$$\gamma = \frac{2\pi N}{60}$$

$$\gamma = 0.267N \quad \ldots (12)$$

4. Determination of Shear Stress (τ)

Shear stress was calculated using the relationship between viscosity and shear rate:

$$\tau = \eta \times \gamma \quad \ldots (13)$$

Substituting:

$$\tau = \eta \times \left(\frac{8}{\pi} \times \Omega\right) \quad \ldots (14)$$

Where:

τ = Shear stress (Pa)

η = Apparent viscosity (Pa·s)

γ = Shear rate (s^{-1})

5. Herschel–Bulkley Model for Flow Behaviour

The rheological behaviour of gelatinized arrowroot starch dispersions was described using the Herschel–Bulkley model, which is widely used for non-Newtonian fluids:

$$\tau = \tau_0 + K \quad \ldots (15)$$

Where:

τ = Shear stress (Pa)

τ_0 = Yield stress (Pa)

K = Consistency coefficient ($Pa{\cdot}s^n$)

γ = Shear rate (s^{-1})

n = Flow behaviour index (dimensionless)

RESULTS AND DISCUSSION

Physicochemical and Functional Properties of Arrowroot Starch

1. Ash Content

Table 1 shows ash content of arrowroot starch in the present investigation ranged from 1.102 to 1.21%, with a mean value of 1.146 ± 0.056%. This value has been similar with Malki *et al.* (2023) and are marginally higher than those reported by Kaur *et al.* (2010) and Sandoval-Gordillo *et al.* (2014), where ash content in purified arrowroot starch was generally below 1%. Comparable values for root and tuber starches have also been documented by Nuwamanya *et al.* (2010). The compared with other starches such as cassava (0.31%), potato (0.25%), and maize (0.46%), arrowroot starch demonstrates relatively higher mineral content.

From a functional perspective, ash content plays a critical role in influencing gelatinization behaviour, swelling characteristics, and paste stability, as minerals (especially phosphorus) interact with starch molecules and modify hydration properties.

2. pH

Table 1 shows pH values ranged from 7.5 to 7.6, with an average of 7.53 ± 0.058, indicating a neutral nature of the starch. The near-neutral pH observed in this study is comparable with values reported by Malki *et al.* (2023), confirming that properly processed arrowroot starch generally exhibits stable and slightly neutral characteristics. This is slightly higher than the pH values reported by Kaur *et al.* (2010) and Singh *et al.* (2016), where arrowroot starch typically exhibited mildly acidic characteristics (pH 6.0–6.8). Similar variations due to processing conditions have been discussed by Sangeetha-Mishra (2006). Compared to cassava (~5.0) and maize starch (~6.0), the neutral pH of arrowroot starch in this study suggests improved purification and minimal presence of acidic impurities.

pH significantly affects enzyme activity, gelatinization, microbial stability, and product shelf life. Neutral starch systems are preferred in food formulations, pharmaceuticals, and biodegradable materials due to their chemical stability. The neutral pH enhances the versatility and stability of arrowroot starch for diverse applications.

3. Bulk Density

Table 1 shows bulk density was observed between 0.7915 and 0.8235 g/cc, with a mean value of 0.8109 ± 0.017 g/cc, which is comparatively higher than cassava (0.54 g/cc) and maize starch (0.55 g/cc) as reported by Nuwamanya *et al.* (2010) and Abida Ali (2014). Higher bulk density indicates tighter packing of starch granules, reduced inter-particle voids, and improved mass per unit volume. Similar findings were reported by Aulton (2001) and Adebowale *et al.* (2005) for root starch powders.

Functionally, bulk density is important for powder handling, packaging efficiency, flowability, and compressibility, especially in pharmaceutical tablet

Table 1: Shows the Physio-chemical properties of Arrowroot starch sample

Starch	Replications	(a) Ash Content (%)	(b) pH	(c) Bulk density (g/cc)	(d) Particle Size (μm)	(e) Moisture Content (%)	(f) Gel. Temp. (°C)	(g) WAC (g/g)	(h) Swelling Volume (ml)	(i) Swelling Power (g/g)	(j) Solubility (%)
Arrowroot	R1	1.21	7.5	0.7915	45.91	12.41	72	1.7	10.0	11.22	12.88
Starch	R2	1.102	7.5	0.8178	45.44	12.40	72	1.68	10.1	11.79	11.95
	R3	1.128	7.6	0.8235	43.90	12.24	73	1.6	10.2	12.24	12.94
	Mean	**1.146**	**7.53**	**0.8109**	**45.08**	**12.35**	**72.33**	**1.66**	**10.1**	**11.75**	**12.59**
	SD	**0.056**	**0.058**	**0.017**	**1.051**	**0.095**	0.577	0.053	0.10	0.51	0.56

formulations. The high bulk density of arrowroot starch suggests excellent handling properties and suitability for industrial-scale processing.

4. Particle Size

The particle size ranged from 43.90 to 45.91 μm, with a mean of 45.08 ± 1.051 μm, shown in Table 1 which is slightly higher than value reported by Kaur *et al.* (2010). The particle size distribution observed in this study is comparable with the findings of Hoover (2001) and aligns with the range reported by Malki *et al.* (2023) for arrowroot starch granules. Compared with cassava (5–40 μm) and maize (2–30 μm), the observed granules are relatively larger, which may be due to varietal differences or extraction conditions.

Particle size directly influences hydration rate, swelling behaviour, enzymatic digestibility, and rheological properties. Larger granules generally exhibit higher swelling capacity and viscosity due to increased water penetration. The relatively larger particle size enhances functional efficiency in thickening and gel formation applications.

5. Moisture Content

Moisture content ranged between 12.24 and 12.41%, with an average of 12.35 ± 0.095%, shown in Table 1 which is within the acceptable storage limit (<14%) as recommended by AOAC (2010) and Austin (1984). Similar findings reported by Malki *et al.* (2023) and Nuwamanya *et al.* (2010), confirming acceptable storage stability of the starch. Moisture content plays a vital role in determining shelf life, microbial growth, and storage stability. Excess moisture can lead to spoilage, whereas controlled moisture level indicates good storage stability and resistance to microbial deterioration.

6. Gelatinization Temperature

Table 1 shows gelatinization temperature ranged from 72–73°C, with a mean of 72.33 ± 0.577°C, which is consistent with values reported by Singh *et al.* (2016) and Gunaratne and Corke (2007). Compared to potato (~60°C) and cassava (~63–70°C), arrowroot starch exhibits moderate gelatinization temperature, indicating balanced intermolecular bonding strength. This property is crucial for thermal processing, cooking behaviour, and energy efficiency during food preparation. The moderate gelatinization temperature makes arrowroot starch suitable for controlled cooking and industrial processing applications.

7. Water Absorption Capacity (WAC)

Table 1 shows WAC ranged from 1.6 to 1.7 g/g, with a mean of 1.66 ± 0.053 g/g, which is higher than cassava starch (~1.09 g/g) reported by Nuwamanya *et al.* (2010). Similar values have been reported for starch by Roy *et al.* (2020) and Kim, C. and Yoo, B. (2009). This high WAC can be attributed to the presence of hydrophilic hydroxyl groups and the structural arrangement of amylose and amylopectin, which facilitate water binding. Functionally, high WAC improves texture, mouthfeel, consistency, and water retention in food systems and enhances film-forming ability in biodegradable materials.

8. Swelling Volume

The swelling volume ranged from 10.0 to 10.2 ml, with an average of 10.1 ± 0.10 ml shown in table 1, which is significantly higher than cassava starch (~1.42 ml) reported in literature. This observation agrees with studies by Gunaratne and Corke (2007), Malki *et al.* (2023) and Hirsch and Kokini (2002), where swelling is associated with granule expansion upon heating. Higher swelling volume reflects greater water uptake and structural relaxation of starch granules, contributing to viscosity development.

9. Swelling Power

Table 1 shows swelling power ranged from 11.22 to 12.24 g/g, with a mean of 11.75 ± 0.51 g/g, which is higher than maize and wheat starches (Nuwamanya *et al.* 2010). Similar values have been reported by Leach *et al.* (1959) and Adebowale *et al.* (2005). Swelling power reflects the ability of starch to absorb water and expand upon heating, mainly influenced by amylopectin content. The high swelling power

confirms strong gel-forming and thickening properties, beneficial for food and packaging applications.

10. Solubility

Table 1 shows solubility ranged from 11.95 to 12.94%, with a mean of 12.59 ± 0.56%, which is significantly higher than cassava (~1.7%) and other cereal starches. The solubility values observed are in agreement with previous studies by Nuwamanya *et al.* (2010) and also align with the trends reported by Malki *et al.* (2023), indicating good molecular dispersion behaviour. Higher solubility indicates increased leaching of amylose molecules during heating, improving interaction with water. The high solubility supports better functional performance in instant foods and biodegradable film applications.

Rheological properties of gelatinized Arrowroot starch dispersion

Fig. 1 presents the relationship between shear stress (Pa) and shear rate (s^{-1}) for gelatinized arrowroot starch dispersions at different concentrations (5%, 10%, 15%, 20%, and 25% w/v). It is evident that shear stress increased with an increase in shear rate for all concentrations. Moreover, at higher starch concentrations, the magnitude of shear stress was significantly greater, indicating increased resistance to flow due to higher solid content and stronger intermolecular interactions within the system.

The curvature of the flow lines confirms that the dispersions do not follow linear (Newtonian) behaviour. Instead, a decrease in apparent viscosity with increasing shear rate was observed, indicating shear-thinning (pseudoplastic) behaviour. This phenomenon is mainly associated with the alignment of starch molecules (amylose and amylopectin) in the direction of flow and the gradual breakdown of hydrogen bonding within the starch–water network during shearing. Similar behaviour has been reported for arrowroot and other tuber starches by Kaur *et al.*

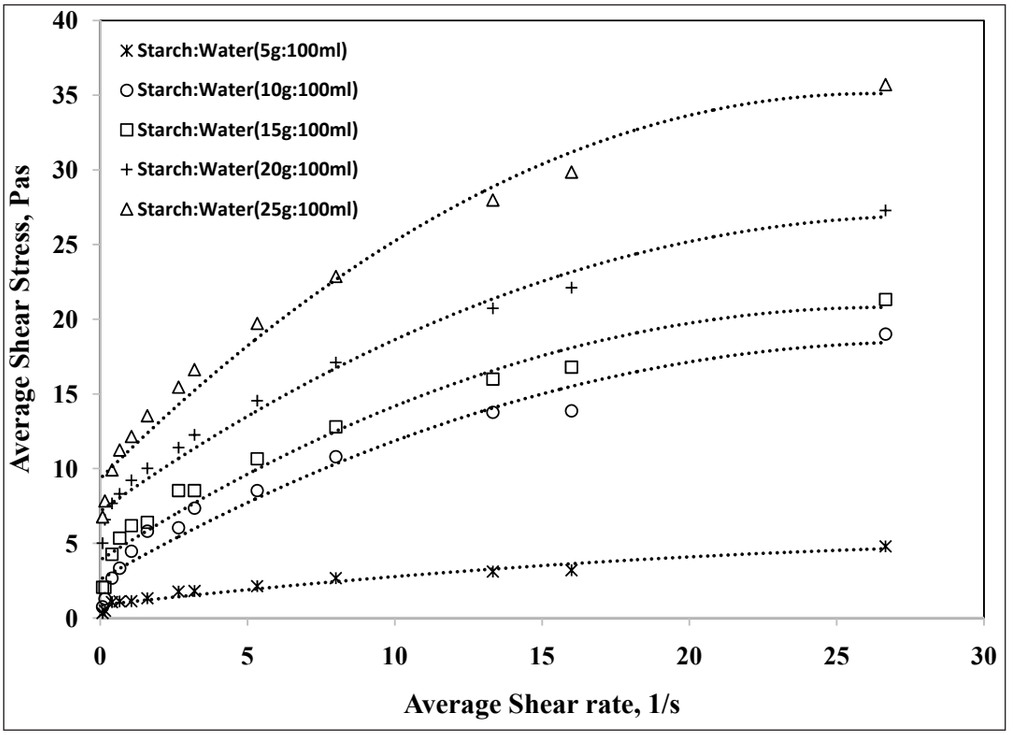

Fig. 1: Shear Stress (Pa) versus Shear rate (1/s) for Arrowroot starch

Table 2: Parameters of Herschel-Bulkley model of Arrowroot starch

Type of Starch	Proportion (g: ml)	Parameters of Herschel-Bulkley model				
		τ_0	K	n	r^2	MSE
Arrowroot	5:100	1.278	0.156	0.946	0.981	0.199
	10:100	1.457	2.678	0.565	0.991	1.483
	15:100	1.537	4.172	0.474	0.998	0.314
	20:100	4.370	4.496	0.496	1.0	0.091
	25:100	5.357	8.343	0.414	0.999	0.437

(2010) and Malki *et al.* (2023), (Hundekari and Swami, 2024).

Herschel–Bulkley Model Parameters

The experimental data an average shear stress vs average shear rate were fitted to the Herschel–Bulkley model, and the obtained parameters are presented in Table 2. The model showed an excellent fit with a high coefficient of determination (r^2 ranging from 0.981 to 1.000), confirming that this model is highly suitable for describing the flow behaviour of arrowroot starch dispersions.

The yield stress (τ_0) increased from 1.278 Pa to 5.357 Pa with increasing starch concentration (5%, 10%, 15%, 20%, and 25% w/v). This indicates that higher force is required to initiate flow in more concentrated systems due to the formation of a stronger internal structure. The presence of yield stress suggests that the dispersions behave like structured fluids, which is typical for gelatinized starch systems.

The consistency coefficient (K) increased from 0.156 to 8.343 Pa.s^n as the concentration increased from 5% to 25% (w/v). This trend indicates that the viscosity of the system increases with starch concentration due to enhanced particle–particle interactions and network formation. Similar increases in consistency coefficient with concentration have been reported in starch systems by Moreira *et al.* (2012).

The flow behaviour index (n) values ranged from 0.946 to 0.414, all of which are less than 1, confirming the pseudoplastic nature of arrowroot starch dispersions. A decreasing trend in 'n' with increasing concentration suggests stronger shear-thinning behaviour at higher concentrations. This behaviour is advantageous in processing operations such as pumping and mixing, where lower viscosity at higher shear rates is desirable.

The mean square error (MSE) values were relatively low (0.091 to 1.483), further confirming the good agreement between experimental and predicted values. This validates the reliability of the Herschel–Bulkley model in describing the rheological behaviour of arrowroot starch dispersions.

CONCLUSION

The present study confirmed that arrowroot starch possesses desirable physicochemical, functional, and rheological properties that support its applicability as a natural biopolymer. The starch showed low ash content (1.10–1.21%), near-neutral pH, and moisture content around 12%, indicating good quality and stability. Functional characteristics such as water absorption capacity (1.6–1.7 g/g), swelling power (11–12 g/g), and solubility (~12%) demonstrate its strong hydration behaviour and suitability for thickening and gelling applications.

Rheological analysis revealed that gelatinized arrowroot starch dispersions exhibited non-Newtonian, shear-thinning behaviour, with flow properties significantly influenced by concentration. The Herschel–Bulkley model provided a good fit to the experimental data ($r^2 \geq 0.98$), confirming the reliability of the observed flow behaviour. The decrease in flow behaviour index and increase in consistency with increasing concentration indicate

the development of a structured network within the dispersion system.

The findings are consistent with previously reported studies, supporting the validity of the results. Based on its overall performance, arrowroot starch can be effectively utilized as a viscosity enhancer, thickening agent, and stabilizer in food systems, as well as in biodegradable and pharmaceutical applications.

GENERATIVE AI DECLARATION

The author(s) confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript, and no images were manipulated using AI. The authors developed and verified all scientific content, data analysis, interpretation of results, and conclusions. The authors take full responsibility for the accuracy, integrity, and originality of the work presented, and no AI tool was listed as an author.

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