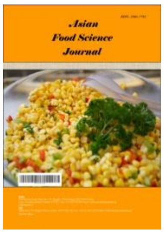

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Variance of Arrowroot (*Maranta arundinacea*) Starch Granule Morphology among Five Different Provinces in Sri Lanka

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Authors' contributions

This work was carried out in collaboration among all authors. Author MKSM conducted research work, data collection and analysis and drafting of the manuscript. Authors JAACW, RHMKR and GCT contributed by developing the concept, research design, scientific advice, correction of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Arrowroot (*Maranta arundinacea*) is an underutilized tuber crop in Sri Lanka that produces a gluten-free, easily digestible starch. This research aimed to determine the variance of arrowroot starch granular morphology among the plants grown in five different provinces (Western, North-Western, Southern, Sabaragamuwa, Uva). Arrowroot starch granules were observed using the light microscope and scanning electron microscope. Oval, irregular globular and spherical shapes were the predominant granule shapes for arrowroot. The mean percentage of oval shaped granules ranged between 48.46 % - 59.34 %. The length and width of the granules were not significantly different among the five provinces. The length of the starch granules ranged between 42.91 - 45.86 µm while the width ranged

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between 30.81 – 32.32 µm. Arrowroot flour samples from five different provinces in Sri Lanka were not significantly different with regard to the starch granular morphology and therefore, arrowroot flour can be utilized in the local food industry without concerning their geographical locations.

Keywords: Arrowroot; granular shape; granular morphology; Maranta arundinacea; starch.

1. INTRODUCTION

The most widely available and cost-effective commodity product is starch, which is the second-largest source of biomass after cellulose. Glucose results from photosynthesis and is stored in chloroplasts of the storage organs of plants like tubers, roots, and rhizomes in the form of granules [1,2]. Starch is utilized in the food industry as a thickening agent, water retentive agent, gelling agent, and colloidal stabilizer to improve texture [3]. Baked products, sauces, soups, confectionaries, ice cream, sugar syrups, snacks, baby meals, and pharmaceuticals are produced from starch [4]. The semi-crystalline granular structure of starch is one of the main factors contributing to its economic competitiveness [5].

Since starch is made in granular form, extraction of starch through wet milling is more prevalent [6]. Amylose and amylopectin are the two main structural components of starch. Amylopectin 80–90% and amylose 10–20% are the most common compositions in starch. Physicochemical properties of starch, such as retrogradation, viscosity, and gel stability, are affected by the differences between these two molecules [1]. When combined with iodine solution, starch turns into blue colour. The linkage between glucose residues in starch is 1-4, while the linkage at branch points is 1-6 [7]. While amylose is amorphous, amylopectin in the granule has a semi-crystalline structure [6]. The hilum (the center of growth) is connected to the surface of the granules by a series of concentric layers known as growth rings of increasing diameter. The circumscribed growth rings themselves comprise shifting crystalline and amorphous zones of varying densities [8]. Depending on the type of plant, the amylose:amylopectin ratio in starch granule characteristics varies. Different botanical sources of starch have distinctive forms, sizes, and morphologies [9].

Starch granules range from submicron to more than one hundred microns. Granules of starch can be formed into spherical, disks, ovals, polygons, domes, elongated rods, and complex starches. The amount and kind of starch both play a significant role in the final texture of the food product [10]. The swelling power, solubility, and digestibility of the starch are particularly affected by the size and form of the granules [11,12]. A larger size of starch granules results in a decreased enzymatic susceptibility [13]. Recently, it has been discovered that the size of the starch granule is a significant factor in both dietary and industrial applications of starches [14].

Industrialists are interested in the introduction of novel starch sources since it has the potential to affect the global market. Starches from roots and tubers have received significant attention recently due to their prospective applications [15,16,17].

Arrowroot (*Maranta arundinacea,* Family: Marantaceae) is an underutilized tuber crop in Sri Lanka which is locally known as “Hulankeeriya” Aerukka” and is used in folk medicine. Arrowroot tuber starch has emerged as a viable dietary remedy for individuals on special diets who have celiac disorders [18]. Moreover, for the purpose of production of films with good functional properties, arrowroot starch has unique physicochemical characteristics, including a high amylose content (16–27 %) [19,20]. Arrowroot starch has the advantage of excellent digestibility [21] and gelling ability [22,23]. Due to its high digestibility, arrowroot is used to feed children, the elderly, and individuals with digestive issues [3].

In order to determine whether arrowroot flour from any growing region may be used in the future for food applications, the aims of this study were to assess the granular morphology of arrowroot flour and investigate variations among flour samples from five different provinces in Sri Lanka with a view to enhancing the utilization of arrowroot plant in Sri Lanka.

2. MATERIALS AND METHODS

2.1 Sample Collection

In total, sixteen locations were selected in Sri Lanka, representing five provinces: Gampaha, Divulapitiya, Horana, Mahara (Western province), Kegalle, Deraniyagala, Rambukkana (Sabaragamuwa province), Thihagoda, Matara, Galle (Southern province), Hakgala, Welimada, Badulla (Uva province), Makandura, Kuliyapitiya, Kurunegala (North-Western province). Arrowroot tubers were harvested at correct maturity and the flour was prepared by wet extraction method [20]. Prior to further examination, samples were sifted through a 425 µm sieve, packed in airtight containers, and placed in the freezer (-18 °C).

2.2 Determination of Starch Granular Morphology

A 1:1 (v/v) ratio of distilled water to glycerin was used to create the starch suspension. After staining a sample of starch suspension with a 1.0% iodine solution, a thin smear was made on a glass slide and covered with a cover slip. A light microscope (OPTICA Microscope B-290, Italy) was used to measure the size of the arrowroot starch granules and the OPTICA Pro View digital camera program N-plan was used as the imaging software [5]. Dry arrowroot starch powder was deposited in a thin layer on adhesive metallic support and then sputter coated with gold. The metalized samples were examined using a scanning electron microscope (SU 6600, HI-2108-003, Japan) operated at 5 kV [24].

2.3 Experimental Design and Statistical Analysis

Measurements were done for arrowroot flour samples from five different provinces as triplicates. Data analysis was done using analysis of variance (ANOVA) at 0.05 confidence level from MINITAB statistical software (version 19).

3. RESULTS AND DISCUSSION

The variations in length (µm) and width (µm) of arrowroot starch granules from five different provinces are presented in Table 1. Spherical shape average-sized starch granules were selected to take the measurements. According to the measurements taken on arrowroot starch samples, the length and width of the granules from five different provinces of Sri Lanka were not statistically significant ($P<0.05$). The mean length of starch granules ranged from 42.91 - 45.86 µm while the width ranged between 30.81 – 32.32 µm. Previous studies conducted in Brazil have recorded that the average granule size in arrowroot starch was 24.97 µm, while the range of sizes was 20 µm - 40 µm [3,25] while in another study the average starch granule size was given as 56.60 µm [26]. The size of oval shape arrowroot starch granules varied from 8.6 - 42 µm as reported by [27,28]. A study conducted in Sri Lanka has indicated the average granule diameter as 23.7 µm [29]. Arrowroot starch granule dimensions of the current study are compatible with the results of past research studies. However, starch granule sizes may vary due to the difference in their botanical origins [30]. Nevertheless, there was no significant variation in arrowroot starch granule sizes from different geographical locations within Sri Lanka.

Based on the granular size, the following classes for the size of starch granules have been identified: Very small (<5 µm), Small (5-10 µm), medium (10-25 µm), and large (>25 µm) [12]. According to this categorization, arrowroot starch granules can be categorized as 'large' because their size falls between 30 - 46 µm. Most cereal starch granules are smaller than those from tuber and legume starches [5]. Size distribution varies depending on the stage of maturity of the plant and the form of tuber [25,31]. In the current study, the arrowroot tubers used were at the harvesting stage for the market.

Granule shape is a highly important characteristic to identify the uniqueness of the starch. According to published reports, the granules of arrowroot starch were diverse in shape and size, varying from elongated, spheroid, and oval in shape [3,26,27,28,32]. Granules of starch have a smooth surface without any indications of fissures [20]. Three identical starch granule shapes were identified in the current study, namely oval, spherical, and irregular globular shapes. Oval shape was the most predominant shape among all samples. Most of the starch granules were oval or spherical with a considerable roundness.

The majority of starch granules, 48.46 % - 59.34 % had oval shapes, which were more common than spherical and irregular globular shapes. The second most common shape was spherical, followed by irregular globular shape. The irregular globular shape is a middle shape between the spherical and oval shapes. Arrowroot from the Western province contained a relatively higher percentage of oval shape starch granules. Nonetheless, the results indicate that a high consistency is present in the granule size and shape of starch from different geographical regions in Sri Lanka.

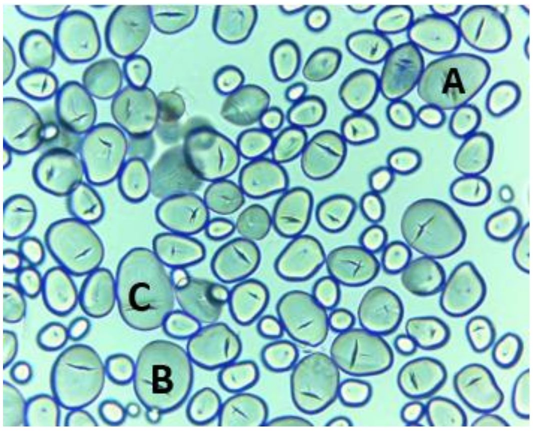
The size of starch granules and starch digestibility were found to be negatively correlated in some previous studies [33,34]. Due to their higher specific surface area for enzyme interaction and response, smaller starch granules are more receptive to enzymatic hydrolysis [35]. In addition to granule size, starch digestibility is also influenced by its shape. The specific surface area of the granule is substantially impacted by the shape of the granule, which ranges from spherical to polyhedral [33].

Table 1. Variation in arrowroot starch granule size from five different provinces in Sri Lanka

Province	Length (μm)	Width(μm)
North-Western province	43.25 ± 4.68^{a}	30.81 ± 3.15^{a}
Sabaragamuwa province	45.86 ± 5.43^{a}	32.32 ± 2.54^{a}
Southern province	42.91 ± 4.50^{a}	31.97 ± 3.01^{a}
Uva province	45.10 ± 4.30^{a}	31.44 ± 3.76^{a}
Western province	44.99 ± 5.06^{a}	31.34 ± 4.16^{a}

Values are Mean ± SD

The same superscript letter in each column represents values not significantly different from each other at p = 0.05



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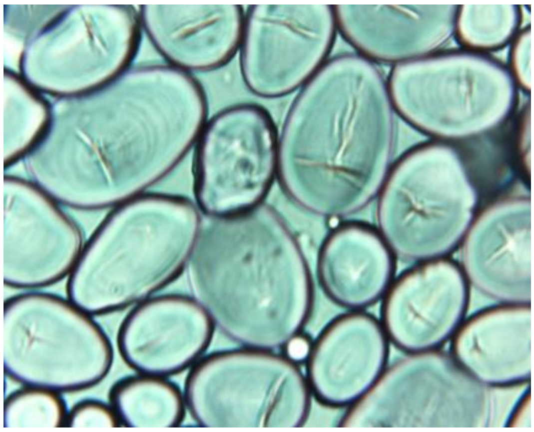

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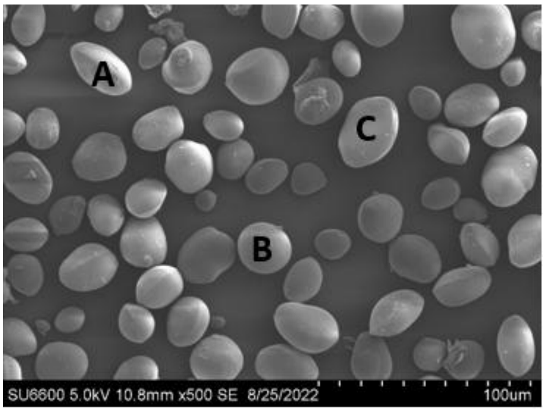

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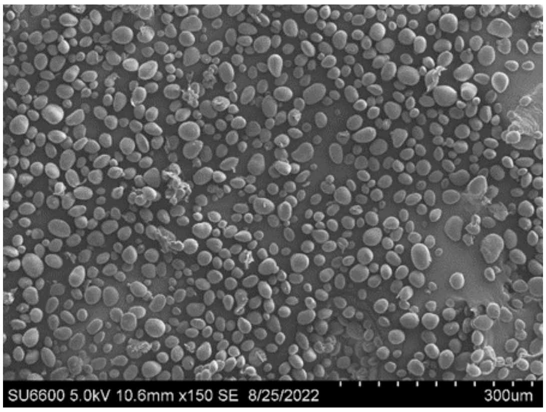

(d)

Fig. 1. (a) Light micrograph (x40) of different shapes of arrowroot starch granules, (b) Light micrograph (x100) of different shapes of arrowroot starch granules, (c) Scanning electron microscope image (x500) of arrowroot starch granules, (d) Scanning electron microscope image (x150) of starch granules (A – spherical shape, B – Oval shape, C- Irregular globular shape)

The quality of starch is significantly influenced by the size of the starch granules. Smaller granules have worse swelling characteristics than larger ones, which causes them to gelatinize more slowly. They also have poor storing and flavor properties. The starch content of starch grains reduces as their average size grows but their starch content increases. The size and shape of the starch grains affect the temperature of gelatinization, the quantity of bound moisture, the viscosity of the starch paste, the ratio of the starch fractions, the color of the iodine sample, and other physicochemical features [36]. Because arrowroot is having large starch granules, it gelatinizes quickly and forms a viscous gel. Therefore, arrowroot flour can be used as a thickener or stabilizer in the food industry.

4. CONCLUSION

There are three predominant starch granular shapes for arrowroot: oval, spherical, and irregular globular shape. Among them, the oval shape is the most prevalent shape (48.46 % - 59.34 %) among all the collected flour samples while the spherical shape is the second most prevalent (23.48 % - 29.82 %). The length and width of arrowroot starch granules did not significantly differ among flour samples. The length of granules ranges from 42.91 - 45.86 µm while the width of ranged from 30.81 - 32.32 µm. Arrowroot flour samples from the five provinces were not significantly different in terms of the starch granular morphology and the flour could be used in the local food industry irrespective of the growing location.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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