Original Research Article

VARIANCE OF ARROWROOT (*MARANTA ARUNDINACEA*) STARCH GRANULE MORPHOLOGY AMONG FIVE DIFFERENT PROVINCES IN SRI LANKA

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 between 30.81 – 32.32 µm. Arrowroot flour samples from five different provinces in Sri Lanka were not significantly ($P<0.05$) 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, granule morphology, Maranta arundinacea, starch

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 (Vegh, 2002; Qiang, 2005). Starch is utilized in the food industry as thickening agents, water retentive agents, gelling agents, and colloidal stabilizers to improve texture (Souza *et al*., 2019). Baked products, sauces, soups, confectionaries, ice cream, sugar syrups, snacks, baby meals, and pharmaceuticals are produced from starch (Burrell, 2003). The semi-crystalline granular structure of starch is one of the main factors contributing to its economic competitiveness (Wijesinghe *et al*., 2014).

Since starch is made in granular form, extraction of starch through wet milling is more prevalent (Jane, 2006). 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 (Vegh, 2002). When combined with iodine solution, starch turns into blue colour. The linkage between glucose residues in starch is 1-4, while linkage at branch points is 1-6 (Lentfer *et al*., 2002). While amylose is amorphous, amylopectin in the granule has a semi-crystalline structure (Jane, 2006). 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 (Copeland *et al*., 2009). Depending on the type of plant, the amylose:amylopectin ratio in starch granule characteristics vary.

Different botanical sources of starch have distinctive forms, sizes, and morphologies (Jane, 1994).

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 (Biliaderis, 1999). The swelling power, solubility, and digestibility of the starch are particularly affected by the size and form of the granules (Svilhus *et al*., 2005; Adejumo *et al*., 2011). A larger size of starch granules results in a decreased enzymatic susceptibility (Franco and Ciacco, 1992). Recently, it has been discovered that the size of the starch granule is a significant factor in both dietary and industrial applications of starches (Campbell *et al*., 1996).

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 a significant attention recently due to their prospective applications (Takeiti *et al*., 2007; Nwokocha *et al*., 2009; Jyoti and Konwar, 2011).

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 (Madhava *et al*., 2012). Moreover, for the purpose of production of films with good functional properties, arrowroot starch has unique physicochemical characteristics, including the high amylose content (16–27 %) (Moorthy, 2002; Nogueira *et al*., 2018). Arrowroot starch has the advantage of excellent digestibility (Villas-Boas and Franco, 2016) and gelling ability (Hoover, 2001; Charles *et al*., 2016). Due to its high digestibility, arrowroot is used to feed children, the elderly, and individuals with digestive issues (Souza *et al*., 2019).

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.

Materials and methods

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 following the method described by Nogueira *et al*. (2018). Prior to further examination, samples were sifted through a 425 µm sieve, packed in airtight containers, and placed in the freezer (-18 °C).

Determination of starch granular morphology

The method described by Wijesinghe *et al*. (2014) was slightly modified in order to observe the starch granules' 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. Dry arrowroot starch powder was deposited in a thin layer on an adhesive metallic support and then sputter coated with gold. The metallized samples were examined using a scanning electron microscope (SU 6600, HI-2108-003, Japan) operated at 5 kV (Horovitz *et al.*, 2011).

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).

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 starch granules' mean length 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 (Leonal, 2007; Souza *et al.*, 2019) while in another study the average starch granule size was given as 56.60 µm (Valencia *et al*., 2014). The size of oval shape arrowroot starch granules varied from 8.6 - 42 µm as reported by Erdman (1986) and Peroni *et al*. (2006). A study conducted in Sri Lanka has indicated the average granule diameter as 23.7 µm (Wickramasinghe *et al*., 2009). 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 (Lindeboom *et al*., 2004). Nevertheless, there was no significant variation in arrowroot starch granule sizes from

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

Province	Length of starch granule (µm)	Width of starch granule (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]

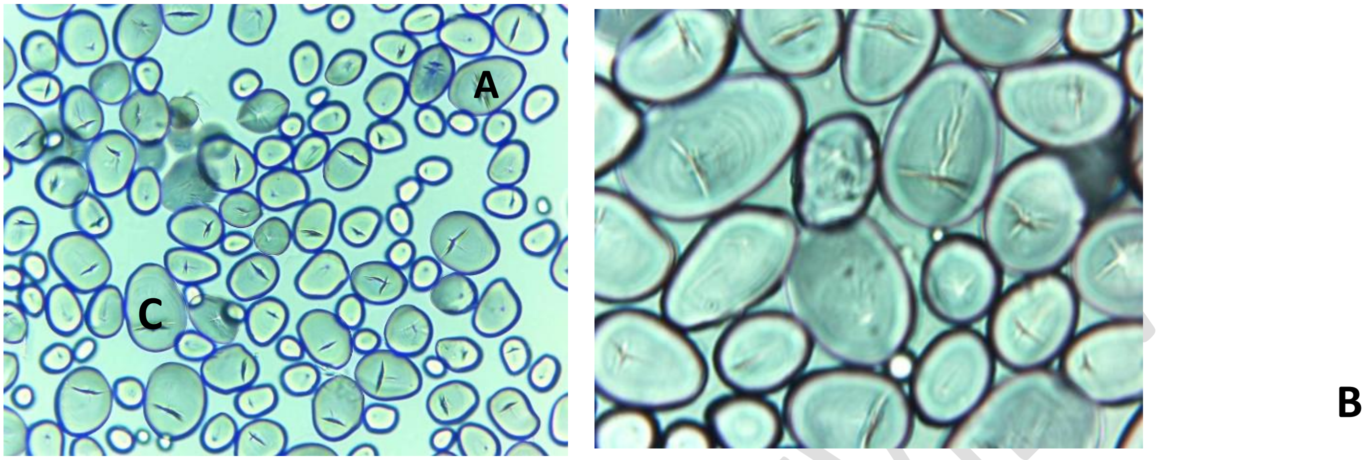
Values are Mean ± SD

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

different geographical locations within Sri Lanka.

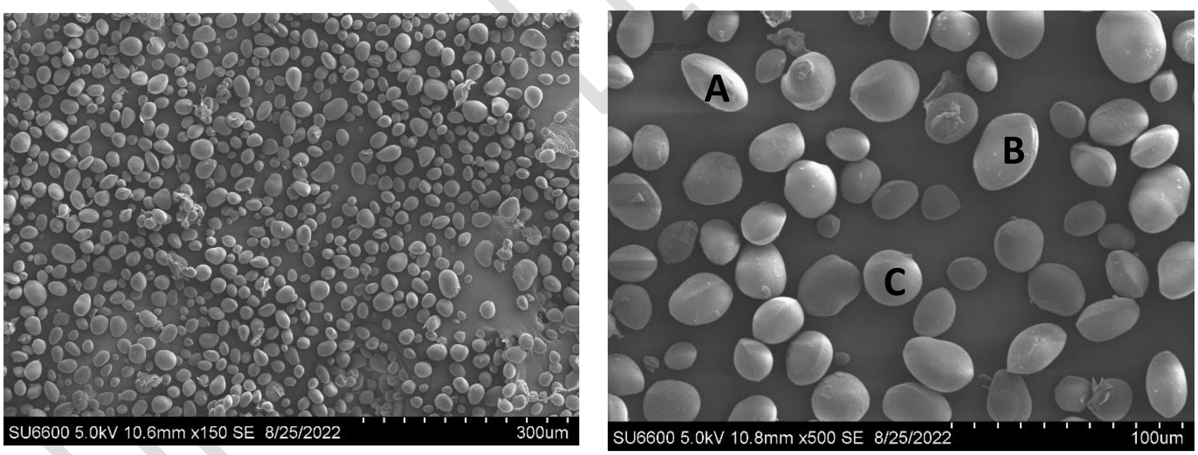
Based on the granular size, Adejumo *et al*. (2011) identified the following classes for the size of starch granules: Very small (<5 µm), Small (5-10 µm), medium (10-25 µm), and large (>25 µm). According to this categorization, arrowroot starch granules can be categorized as 'large' because their size falls between 30 - 46 µm. Most cereal starch granules are smaller than those from tuber and legume starches (Qiang, 2005). Size distribution varies depending on the plant's stage of development and the form of tuber (Singh *et al*., 2003; Leonal, 2007). In the current study, the arrowroot tubers used were at the harvesting stage for 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 (Erdman, 1986; Perez *et al*., 1997; Peroni *et al*., 2006; Valencia *et al*., 2014; Souza *et al*., 2019). Granules of starch have a smooth surface without any indications of fissures (Nogueira *et al*., 2018). 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.



(a) (b)

Figure 1. (a) Light micrograph (x40) of different shapes of arrowroot starch granules (A – Spherical shape, B – Oval shape, C – Irregular globular shape). (b) Light micrograph (x100) of different shapes of arrowroot starch granules



(a) (b)

Figure 2. (a) Scanning electron microscope images of arrowroot starch granules (A – Spherical shape, B – Oval shape, C – Irregular globular shape)

The distribution of granular shapes in the flour samples are depicted in Table 2.

Table 2. Distribution of starch granule shapes of arrowroot from five different provinces in Sri Lanka

Province	Oval shape %	Spherical shape %	Irregular globular shape %
North-Western	48.46±8.57[b]	29.82±3.70[a]	21.72±8.12[a]
Sabaragamuwa	49.54±6.12[b]	28.98±4.50[a]	21.48±5.05[a]
Southern	55.72±7.09[ab]	27.99±6.95[a]	16.29±2.81[a]
Uva	48.82±8.37[b]	29.08±5.17[a]	22.10±7.89[a]
Western	59.34±6.86[a]	23.48±6.57[a]	17.19±4.26[a]

Values are Mean ± SD

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

The maj ority 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 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.

Conclusions

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.

References

Adejomo, A., Aderibigbe, A.F., Layokun, S.K. 2011. Cassava Starch: Production, Physicochemical Properties and Hydrolysation- A Review. Advances in Food and Energy Security, **2**.

Wickramasinghe, H.A.M., Takigawa, S., Matsuura-Endo, C., Yamauchi, H., Noda, T. 2009. Comparative analysis of starch properties of different root and tuber crops of Sri Lanka, Food Chemistry, **112**(1), 98-103.

Biliaderis, C.G. 1999. The structure and interaction of starch with food constituents, Can J physiol pharmacol. **69**, 60-78.

Burrell, M.M. 2003. Starch: the need for improved quality and quantity – an overview. *Journal of Experimental Botany*, **54**, 451-456.

Campbell, M.R., Li, J., Berke, T.G., Glover, D.V. 1996. Variation of Starch Granule Size in Tropical Maize Germ Plasm. *Cereal Chem*. American Association of Cereal Chemists, Inc. 1996;,**73**(5):536-538.

Charles, A.L., Cato, K., Huang, T.C., Chang, Y.H., Ciou, J.Y., Chang, J.S., et al. 2016. Functional properties of arrowroot starch in cassava and sweet potato composite starches. Food Hydrocolloids, **53**, 187-191.

Copeland, L., Blazek, J., Salman, H., Tang, M.C. 2009. Form and functionality of starch, *Food hydrocolloids*, **23**, 1527-1534.

Erdman, M.D. 1986. Starch from Arrowroot (*Maranta arundinacea*) grown at Tifon, Georgia, Cereal Chemistry, **63** (39), 277-279.

Franco, C.M.L. and Ciacco, C.F. 1992. Factors that Affect the Enzymatic Degradation of Natural Starch Granules. Effect of the Size of the Granules. *Starch/Starke*, **44**, 422-426.

Hoover, R. 2001. Composition, molecular structure, properties and modification of pulse starches: A review. *Carbohydrate polymers*, **45**(3), 253-267.

Horovitz, O., Cioica, N., Jumate, N., Pojar-Fenesan, M., Balea, A., Liteanu, N., Mocanu, A., Tomodia-Cotisel, M. 2011. SEM Characterization of starch granules. Studia ubb Chemia,**1**,212-219.

Jane, J. 2006. Current understanding on starch granule structures. J. Appl. Glycosci, **53**, 205-213.

Jane, J., Kasemsuwan, T., Leas, S., Zobel, H., Robyt, J.F. 1994. Anthology of starch granule morphology by scanning electron microscopy. Starch/Starke, **46**, 121-129.

Jyoti, P.S, and Konwar, B.K. 2011. Physicochemical properties of starch from aroids of north east India. *Int. J. Food Prop*. DOI: 10.1080/ 10942912.2010.491929.

Lentfer, C.J., Therin, M., Torrence, R. 2002. Starch grains and environmenta reconstruction : a modern test case from west new Britain, Papua New Guinea. Archaeol. *Sci*. **29**,687-698.

Leonal, M. 2007. Analise de forma e tamanho de granulos de amidos de diferentes fonts botanicas. Ciencia e Technologia de Alimentos, **27**,579-588.

Lindeboom, N., Chang, P.R., Tyler, R.T. 2004. Analytical, Biochemical an Physicochemical Aspects of Starch Granule Size, with Emphasis on Small Granule Starches: A Review. Starch/Stärke, **56**,89-99.

Madhava, N.M., Sheema, F., Ragu, S.S., Ramasamy, R., Manisha, G. 2012. Morphological, Structural, and functional properties of Maranta (*Maranta arundinacea* L) Starch. Food science and Biotechnology, **21**, 747-752.

Moorthy, S.N. 2002. Physicochemical and functional properties of tropical tuber starches: A review. Starch/Starke, **54**, 559-592.

Nogueira, G.F., Fakhouri, F.M., Oliveira, R.A. 2018. Extraction and characterization of arrowroot (*Maranta arundincea*) starch and its application in edible films, Carbohydrate polymers, **186**,64-72.

Nwokocha, L.M, Williams, P.A. 2009. Some properties of white and yellow plantain (*Musa paradisiaca*, normalis) starches. Carbohyd. Polym. **76**,133-138.

Perez, E., Larez, M., Gonzalez, Z. 1997. Some characteristics of sagu (*Canna edulis*) and zulu (*Maranta* sp) rhizomes. Journal of Agricultural and Food chemistry, **45**, 2546-2549.

Peroni, F.H.G., Rocha, T.S., Franco, C.M.L. 2006. Some structural and physicochemical charcteristics of tuber and root starches, Food. Sci. tech. Int.,**12**(6),505-513.

Qiang L. 2005. Chemistry,physical properties and applications, *Food carbohydrates*, (Steve W .Cui), CRC press, ISBN:978-0-8-493-1574-9, DOI 10.1201/9780203485286.ch7.2005.

Singh, N., Singh, J., Kaur, L., Sodhi, N.S., Gill, B.S. 2003. Morphological, thermal and rheological properties of starches from different botanical sources. Food Chemistry. **81**, 219-231.

Souza, D.C., Silva, R.J., Guerra, T.S., Silva, L.F.L., Resende, LV., Pereira, J. 2019. Characterization of arrowroot starch in different agronomic managements. Rev. Ceres, Vicosa, **66**(5), 323-332.

Svihus, B, Uhlen, A.K, Harstad, O.M. 2005. Effect of starch granule structure, associated components and processing on nutritive value of cereal starch: A review, Elsevier; Animal Feed Science and Technology. **122**(306), 303-320.

Takeiti, C., Fakhouri, F., Ormenese, R., Steel, C., Collares, F. 2007. Freeze-thaw stability of gels prepared from starches of non-conventional sources. Starch/Starke, **59**, 156-160.

Valencia, G.A., Moraes, I.C.F., Lourenco, R.V., Habitante, Bittante, A.M.Q.B., Sobral, P.J.A. 2014. Physicochemical properties of Maranta (*Maranta arundinacea* L.) starch, International journal of food properties, **18**, 1990-2001.

Vegh, K.R. 2002. Starch bearing crops as food sources, Cultivated plants primarily as food sources.**1**. ISBN: 978-1-84826-100-6.

Villas-Baos, F, and Franco, C.M.L. 2016. Effect of bacterial β-amylase and fungal α-amylase on the digestability and structural characteristics of potato and arrowroot starches. Food Hydrocolloid*s*, **52**, 795-803.

Wijesinghe, J.A.A.C., Wickramasinghe, I., Saranandha, K.H. 2014. Variance of Granular Morphology in Kithul ***(Caryota urens)*** Flour among Five Different Growing Areas in Sri Lanka, International Journal of Multidisciplinary Studies *(IJMS),* **2**(1),74-78.