Introducing Daluga (*Cyrtosperma merkusii*) starch from corms collected in Siau Island, North Sulawesi

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Abstract. *Daluga* (*Cyrtosperma merkusii*) found naturally growing at some sites inside Siau Island, North Sulawesi, Indonesia. This plant is an aroid, known as giant swamp taro, and its corm is edible. Very little information known about the plant and corm, and none for its starch. The tendency surfaced is that the plant has been abandoned despite of the corm potency may serve as food source. The same practices also happened around the islands on the same region: even the statistics shown that daluga is excluded from both food expenditure and food crops consideration (BPS 2013). For that reason, this research mainly focus on the study of *daluga* corm starch that has never been studied or reported before. The major findings are starch yield, chemical composition, and granules morphology studied from scanning electron microscopy (SEM) images. The data shows that *daluga* starch is unimodal with average size of 12.50 µm and crystalline type A. The average starch yield is 14.70%, and has medium to low amylose content that shall give good mouthfeel taste. These findings shall possibly support more research and utilization of daluga starch, improving people’s knowledge about it, thus it will benefit researchers or islands communities in the future, as it is a natural resource of food found on these islands of Indonesia.

Keywords: daluga, giant swamp taro, Indonesia, starch, scanning electron microscopy

1. Introduction

*Cyrtosperma merkusii* species’ synonym are including *Arisacontis chamissonis* Schott, *Cyrtosperma bantamense* Koord., *Cyrtosperma chamissonis* (Schott) Merr., *Cyrtosperma cuspidilobum* Schott, *Cyrtosperma dubium* Schott, *Cyrtosperma edule* Schott ex Seem, *Cyrtosperma ferox* N.E.Br. and Linden, *Cyrtosperma intermedium* Schott, *Cyrtosperma lasioides* Griffith, *Cyrtosperma merkusii* (Hassk.) Schott, *Cyrtosperma merkusii* var. *giganteum* Nadeaud, *Cyrtosperma merkusii* var. *intermedium* (Schott) Engl., *Cyrtosperma nadeaudianum* J.W.Moore, and *Lasia merkusii* Hasskarl. [1]. It belongs to the family of Araceae, and the corm is edible. The tuber is mentioned as “corm”, structurally plant stems, with nodes and internodes with buds and produce adventitious roots and at the top of the corm. One or a few buds grow into shoots that produce normal leaves and flowers as seen illustration given in figure 1.

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Figure 1. Illustration of *daluga* (*Cyrtosperma merkusii*) plant [2].

*Daluga* is the local name for this giant swamp taro, used in Siau Island and the neighboring islands located in the North Sulawesi waters, Indonesia. The corm used to be an important staple food in the North Sulawesi, however the popularity has been decreasing since rice, corn, and cassava were introduced [3]. It has also been an underutilized tuber in the Pacific countries, grown in poor soils as subsistence crop since prehistoric era [4][5]. This fact shows that there was a tendency of neglecting this taro as locally available carbohydrate source by the local community. The least utilization indicates the least information known about *daluga* starch. The studies published were still limited to the plant distribution, botany, and nutritive properties of its corm as raw or cooked one [6] [7][8][9]. No particular study focused specifically on *daluga* starch characteristics so this study important to be conducted for that purpose.

Native starches are usually characterized by parameters such as the yield from its source, chemical composition, granular morphology, molecular structural, and physicochemical properties [10]. These properties would determine cooking results, gelling tendencies, freeze-thaw stability, and so on [11]. Some desirable food-grade starch characteristics would include acceptable texture, mouthfeel, and paste clarity [12]. This paper presents *daluga* corm starch structural characteristics as given by SEM and X-ray diffractograms (XRD), for sufficient structural characteristics, and chemical composition information. The main purpose is to give knowledge that would promote more studies and use of *daluga* starch.

2. Materials and Method

2.1. Materials and location
The *Daluga* corms were collected from Siau Island of Sitaro District of North Sulawesi, Indonesia. The location is indicated on the map by a red dot. The plant materials verification was conducted at the Herbarium Bogoriense of Research Center for Biology in Indonesian
Institute of Sciences (LIPI) Cibinong, West Java. Chemicals required for experimentation and analysis were used.

![Figure 2. Map of Indonesia; the red dot indicating location of Siau Island.](image)

2.2. Method

2.2.1. Starch Extraction. Daluga starch was extracted from the corms collected from Siau Island and purified by washing-sedimentation cycles with 0.05N NaOH, dried, and stored in a closed container until use [13].

2.2.2. Yield and Chemical Composition. Starch yield was calculated as the percentage of starch obtained to the initial weight of tuber. Total starch was quantified with glucose determination according to phenol-sulfuric acid method [14]. Chemical composition was analyzed according to the standard methods [15][16] and amylose content of the starch was analyzed according to the iodine affinity method [17].

2.2.3. Observation on Starch Morphology. Starch samples were observed with a scanning electron microscope (JEOL JSM-5310LV) operating at an acceleration voltage of 20 kV and 7500×, 5000×, 2000×, and 1000× magnifications. Granular shape and size were studied, and granule diameter was estimated by measuring 20-30 randomly selected granules from minimum triplicate microphotographs [18].

2.2.4. Starch Crystalline Analysis. The starch samples were exposed to the X-ray beam from the X-ray generator (GBC) operating at 40 kV and 40 mA with Cu radiation (λ = 1.54056Å). The scanning regions of the diffraction angle 2θ were 2-30°. The XRD pattern is determined as A, B, or C type [19].

2.2.5. Statistical Analysis. Experimental data were computer recorded analysis was performed using Excel 2010 (Microsoft Corp.) and SPSS 23 (IBM Corp., USA) software.

3. Results and Discussions

3.1. The Daluga Plant

*Daluga* plants were found grow on many sites on southern part of Siau Island where there are most of the springs are and where many rivers flow. These are including the open, shaded rocky mountain, and riverbank areas. At the riverbank sites, the plant grows side to side with sago trees. The specific features of the plant that made it easy to identify it are the wide leaves on top of tall petioles, and the shoots gathered at a mother plant. The spikes near the base of its petioles are also helpful in differentiate the plant from other aroids such as taro and tannia. The sites are given in figure 2.
Figure 3. Daluga growing sites at the open (A), shaded rocky mountain (B), and riverbank (C) areas.

The daluga corm is rich in starch and non-starch polysaccharides and this corm is the largest in size among the important starch-producing aroids such as Alocasia macrorrhiza (giant taro), Amorphophallus companulata (elephant foot yam), Colocasia esculenta (taro), and Xanthosoma sagittifolium (tannia). Based on previous reports, the carbohydrate content of sago, cassava, tannia, taro, giant taro, daluga, elephant foot yam, and potato are 83.4%, 34.2%, 30.2%, 28.81%, 26.53%, 23.66%, 18.54%, and 17.7% respectively from the highest to the lowest amount as mentioned in previous studies [6] [7][20].

Figure 4. Features of daluga spathe and spadix (A), corms (BC), leaf (D), starch (E), and a cross-section of large corm measuring 23 cm (F).

For this study purpose in preparing the starch samples, the corms were picked from several sites. The color of corms collected from Siau Island range from white to yellowish, and some with specific root-like texture as seen from the cross-section of the corm (figure 3). On the other hand, the appearance of daluga starch is white regardless of these corm colors. The plant materials used in study were also verified by LIPI Cibinong and officially issued in an identification letter number 2363/IPH.1.01/If.07/XII/2015 (table 1).
3.2. Starch Yield and Chemical Composition

The consumption of tubers based carbohydrate was said to be related to low social status, and that is why the consumption decreases every generation because the children are not suggested to follow the diet pattern of their parents for that reason [21][22]. Locally in northern islands of North Sulawesi, *daluga* has been excluded from both food expenditure and food crops consideration based on 2013 expenditure on food data. The locals’ spending for foods (carbohydrate) were allocated as 22.53% for rice, and only 1.61% for tubers, in which the tubers reported were only consisted of cassava and sweet potato [23].

| Table 1. *Daluga* starch yield and chemical composition. |
|----------------------------------------------------------|
| Parameter                  | Range            | Average |
|----------------------------|------------------|---------|
| Yield (%)                  | 7.22 – 22.95     | 14.70   |
| Proximate (%):             |                  |         |
| Moisture                   | 12.63 – 13.99    | 13.11   |
| Ash                        | 0.14 – 0.31      | 0.20    |
| Protein                    | 0.28 – 0.30      | 0.01    |
| Crude fat                  | 0.05 – 0.23      | 0.10    |
| Carbohydrate*              |                  |         |
| - *wet basis*              | 85.33 – 87.18    | 86.62   |
| - *dry basis*              | 99.21 – 99.78    | 99.47   |
| Starch (%)                 | 84.47 – 99.85    | 94.34   |
| Amylose                    | 21.04 – 29.55    | 24.97   |
| Amylopectin*               | 63.43 – 70.30    | 69.37   |
| P (mg/100g)                | 0.00 – 10.0      | 5.00    |
| Minerals (mg/100g)         |                  |         |
| K                          | 10.0 – 30.0      | 20.0    |
| Mg                         | 10.0 – 40.0      | 25.0    |
| B*                         | 0.111 – 0.326    | 0.22    |
| Fe**                       | *nd* – 7.20      | 7.20    |
| Cu                         | *nd*             | *nd*    |
| Mn**                       | *nd* – 1.32      | 1.32    |
| S                          | 20.0             | 20.0    |
| Zn                         | *nd*             | *nd*    |
| Pb                         | 2.36             | 2.36    |
| Cd                         | 0.214            | 0.214   |
| Cr                         | 0.307            | 0.307   |
| Na                         | 10.0             | 10.0    |
| Ca                         | 70.0             | 70.0    |

Values are estimated in dry basis, except for moisture content. *nd*: not detected, *by difference*. *one or more samples’ value is “nd”, therefore the data given are from detected ones.

The preference of starch utilization depends on the known properties of the starch; so lesser known will lead to lesser utilization [24][25]. For this reason, introducing the *daluga* starch would help enrich and renew the people’s knowledge of the tuber and the starch, and in return, it would be considered to be taken into their menu. Providing more options for carbohydrate source is also important in ensuring food security, especially if taken from local natural resources. The starch yield from major tuber and root ranged between 16 to 24%, low in lipid content (<1%), and contain a higher level of ash and lower level of protein than the cereal starches [26]. Similar to these tuber starches, *daluga* starch share the same properties such as the average yield of 14.70%. This indicates that *daluga* starch can be as available as other tuber starches which consumed in more numbers and have fulfil many applications.
Figure 5. Scanning electron micrographs (magnification 5000× and 2000×) of *daluga* starch.

Figure 6. Size distribution of *daluga* starch granules (top) and X-ray diffraction spectra of native *daluga* starch (bottom).

The purified *daluga* starch contained low levels of ash, protein, and lipid as an expected result known from other reports of the same procedure [27]. The average amount of amylose is in the range of typical aroids, considered medium-low amylose starch (<40%) which has good storage and freeze-thaw stability and better mouthfeel taste, thus it is good for direct use in food and industrial applications [11][12][10].
3.3. Starch Morphology & Crystalline Type

SEM has long been employed to study starch morphology. Based on SEM images, specific starch granules characteristics can be studied. It may show some characteristics such as pores on the surface, shape, or size of the starch granules [28]. Wheat and barley starch granules were found to have pores, but aroids have none [10]. The starch extracted from daluga corms was scanned on multiple magnifications to observe the granule morphology (Figure 4). The majority shapes of daluga starch granules were round and hemispherical. These shapes are quite similar to the starch of tannia (Xanthosoma sagittifolium) [18].

These daluga starch granules were monomodal and non-uniform in size. The average granule size is 12.50 μm. Based on this, the average daluga starch granules are larger than the average size of other tuber starches such as cassava (8.43 μm) and taro (6.54 μm) [29]. Any unknown starch can be identified by microscopic examination of the granules that are compared with previously collected data of starches from various botanical source. Knowing the features of daluga starch will benefit future identification of starch in investigation.

X-ray diffractograms (XRD) may also give structural characteristics of the starch, such as degree of crystallinity and the crystalline type of either A-, B-, or C-type. The A-type starch is characterized by strong doublet peak at 2θ ≈ 17°, 18°, the B-type give a pronounced peak at 2θ ≈ 5°, and broad peaks at 2θ ≈ 23°, and the C-type starches exhibit major peaks at 2θ ≈ 5°, 15°, 17°, 18°, and 23° [30] [31][25].

Starch granules have semi-crystalline properties thus the starch doesn’t soluble in water at room temperature [27]. In granules, the external chains of amylopectin crystalize to give A, B, of C-type polymorph [28].The XRD pattern of daluga starch showed an A-type pattern of high peak intensify on 15°, 17°, 18°, and 23° diffraction angle (Figure 6). The other aroids such as elephant foot yam, taro, and tannia gave similar A-type XRD patterns confirming their similarity to each other [26] [18].

4. Conclusion

Daluga plants were found naturally growing on some sites in southern part of Siau Island. The corms harvested and collected for study were white and yellowish. Regardless of the corm colors the daluga starch is white. The average starch yield is 14.70%, and has medium-low amylose content that shall give good mouthfeel taste. These findings support that daluga starch shall be included as one of the options of food ingredients that are locally available, or utilized for other industrial purposes and developed into various products for larger community consumption. The findings on specific features of daluga starch granules as unimodal with average size of 12.50 μm and crystalline type A are also important for starch database and can readily be used for identification purpose of any unknown starch. These findings hopefully will support more research and utilization of daluga starch, improving people’s knowledge about it, so in the future the potency of this natural resource found on these islands of Indonesia can serve good purposes.

5. References

[1] Lim T K 2015 Edible Medicinal and Non-Medicinal Plants Volume 9, Modified Stems, Roots, Bulbs (Dordrecht (NL): Springer Science and Business Media).
[2] Lebot V 2009 Tropical root and tuber crops: cassava, sweet potato, yams and aroids (London (UK): CABI).
[3] Prana T K, Prana M S and Kuswara T 2003 Taro production, constraints and future research and development program in Indonesia In Guariano L, Taylor M, Osborn T, editors Proceedings of 3rd Taro Symposium 2003 May 21-23 Nadi, Fiji (Suva (FJ): Secretariat of the Pacific Community) pp152-154.
[4] Buden D W and Tennent W J 2011 New records of butterflies from Yap outer islands, micronesia: Fais Island and Ngulu, Ulithi, and woleai Atolls Pacific Sci. 65(1) 117-122.
[5] Lebot V, Ivancic A and Abraham K 2005 The geographical distribution of allelic diversity, a practical means of preserving and using minor root crop genetic resources Exp. Agriculture 41(04) 475-489.

[6] Bradbury J H and Holloway W D 1998 Chemistry of Tropical Root Crops: Significance for Nutrition and Agriculture in the Pacific (Canberra (AU): ACIAR).

[7] Dignan C, B Burlingame B, Kumar S and Aalbersberg W 2004 The Pacific Islands food composition tables (Rome (IT): Food and Agriculture Organization of the United Nations (FAO)).

[8] Englberger L, Schierle J, Kraemer K, Aalbersberg W, Dolodolotawake U, Humphries J, Graham R, Reid A P, Lorens A, Albert K and Levendusky A 2008 Carotenoid and mineral content of Micronesian giant swamp taro (Cyrtosperma) cultivars J. Food Comp. Anal. 21 93-106.

[9] Manner H I 2011 Farm and forestry production and marketing profile for giant swamp taro (Cyrtosperma merkusii). In Elevitch CR, editor. Specialty Crops for Pacific Islands Agroforesty (Hawaii, US: Permanent Agriculture Resources).

[10] Zhu F 2016 Structure, properties, and applications of aroid starch Food Hydrocoll. 52 378-392.

[11] BeMiller J N 1997 Starch Modification: Challenges and Prospects Starch 49(4) 127-131.

[12] Breuning W F, Pyachomkwan K and Sriroth K 2009 Tapioca/ Cassava Starch: Production and Use In: Be Miller J, Whistler R, editors 2009 Starch: Chemistry and Technology, Third Edition (New York, US: Academic Press/Elsevier Inc) 541-568.

[13] Jayakody L, Hoover R, Liu Q, and Donner E 2007 Studies on tuber starches. II. Molecular structure, composition and physicochemical properties of yam (Dioscorea sp.) starches grown in Sri Lanka Carbohydr. Polym. 69 148-163.

[14] Dubois M, Gilles K A, Hamilton J K, Rebers P A and Smith F 1956 Calorimetric method for determination of sugars and related substance Anal. Chem. 28 350-356.

[15] AOAC 2011 Official Method of AOAC International (18th ed. 2005) (Maryland, US: AOAC International).

[16] (SNI) Standar Nasional Indonesia 1992 Cara uji makanan dan minuman (Jakarta, ID: Badan Standarisasi Nasional (BSN)).

[17] Juliano B O 1971 A simplified assay for milled-rice amylose Cereal Sci. Today 16 334-336.

[18] Perez E, Schultz F S and de Delahaye E P 2005 Characterization of some properties of starches isolated from Xanthosoma sagittifolium (tannia) and Colocassia esculenta (taro) Carbohydr. Polym. 60 139-145.

[19] Zobel H F 1984 Gelatinization of starch and mechanical properties of starch pastes Starch: Chem. Technol. 2 285-309.

[20] Yadav B S, Sharma A and Yadav R B 2010 Resistant starch content of conventionally boiled and pressure-cooked cereals, legumes and tubers J. Food Sci. Technol 47(1) 84-88.

[21] Pollock N J 2000 Taro In: Kiple K F, Ornelas K C, editors 2000 Cambridge World History of Food (Cambridge, UK: Cambridge University Press) 218-230.

[22] Englberger L, Marks G C and Fitzgerald M H 2003 Factors to consider in Micronesian food-based interventions: a case study of preventing vitamin A deficiency Public health nutr. 7(03) 423-31.

[23] (BPS) Badan Pusat Statistik 2013 Distribusi Pengeluaran Per Kapita Sebulan Menurut Jenis Pengeluaran Kelompok Makanan di Kabupaten di Kepulauan Siau Tagulandang Biaro 2012-2013. SUSENAS-BPS [Internet] https://sitarokab.bps.go.id/linkTableStatis/view/id/13 [Accessed on July 23, 2016].

[24] Hoover R and Ratnayake W S 2002 Starch characteristics of black bean, chick pea, lentil, navy bean and pinto bean cultivars grown in Canada Food chem. 78(4) 489-498.

[25] Lan X, Li Y, Xie S and Wang Z 2015 Ultrastructure of underutilized tuber starches and its relation to physicochemical properties Food chem. 188 632-640.

[26] Hoover R 2001 Composition, molecular structure, and physicochemical properties of tuber and root starches: A review Carbohydr. Polym. 45(3) 253-267.
[27] Tester R F, Karkalas J and Qi X 2004 Starch structure and digestibility enzyme-substrate relationship *Worlds Poult. Sci. J.* **60**(02) 186-95.

[28] Buléon A, Colonna P, Planchot V and Ball S 1998 Starch granules: structure and biosynthesis *Int. J. Biol. Macromol.* **23**(2) 85-112.

[29] Nwokocha L M, Aviara N A, Senan C and Williams P A 2009 A comparative study of some properties of cassava (*Manihot esculenta, Crantz*) and cocoyam (*Colocasia esculenta, Linn*) starches *Carbohydr. Polym.* **76**(3) 362-367.

[30] Zobel H F 1964 X-ray analysis of starch granules *Meth. Carbohydr. Chem.* **4** 109-113.

[31] Singh V, Ali S Z, Somashekar R and Mukherjee P S 2006 Nature of crystallinity in native and acid modified starches *Int. J. Food Prop.* **9**(4) 845-854.