JOURNAL OF TROPICAL LIFE SCIENCE
2024, Vol. 14, No. 1, 187 – 194
http://dx.doi.org/10.11594/jtls.14.01.18

Research Article

Characterization of Starch Granule of Local Water Yam (*Dioscorea alata* L.) from Lermatang, Tanimbar Island District, Maluku

Hermalina Sinay [1]*, Ritha Lusian Karuwal [1], Fauziah [2], Helena Anaktototy [3]

[1] Biology Education Program Faculty of Teacher Training and Education, University of Pattimura, Ambon 97233, Indonesia
[2] Plant Conservation Research Center, Botanical Gardens and Forestry, National Institute for Research and Innovation Indonesia, Purwodadi, Indonesia
[3] Undergraduate Program, Biology Education Program Faculty of Teacher Training and Education, University of Pattimura, Ambon 97233, Indonesia

Article history:
Submission October 2022
Revised June 2023
Accepted June 2023

**Corresponding author:*
E-mail: elinasinay08@gmail.com

ABSTRACT

Most tuberous crops, for instance, the yam, whose scientific name is *Dioscorea alata*, have food reserves in the form of starch in tubers. Characterization of starch grains of a plant species is pertinent to uncover information on plant taxonomic traits and identify their potential use as food and industrial raw materials. The study aimed to determine the characteristics of starch grains of water yam from Lermatang village, Tanimbar Islands Regency. This study isolated and submitted six accessions of water yam in Lermatang Village. The morphological inspection of the plants used the *Descriptor for Yam* from IPGRI, and sample preparation for observing starch grains employed the fresh section method. The six accessions of *D. alata* found in Lermatang village, Tanimbar Islands, were *Uwi Merah, Uwi Gula, Uwi Pingingsian, Uwi Babulu, Uwi Akiakab*, and *Uwi Petatas*. These yam varieties show differences in their tubers' shape and colors. The study found that starch granules of *D. alata* in each accession varied in terms of granule shape and hilus type. The starch granules revealed dominant triangular, oval, and elliptical shapes and eccentric and concentric hilus types. The starch grain diameter in the six accessions of *Uwi* was categorically large (44.88 – 57.5 µm), with *Uwi Petatas* being the largest. Previous reports have shown that accessions having large starch granule types could be further developed into an array of foods, thus conveying the promising use of the *Uwi Petatas* for such a purpose.

Keywords: Lermatang village, Starch granule, Water yam

Introduction

Starch is a product of photosynthesis usually stored as food reserves in plant organs such as tubers, stems, fruits, and seeds. Starch in plants is the main carbohydrate, a polysaccharide consisting of two kinds: amylopectin and amylose [1]. Hence, starch utilization is wide-ranging, comprising various food and non-food industries in original and modified forms [2-3]. Xiao *et al.* [1] also stated that aside from being the main carbohydrate source and energy for humans, starch is also used as a raw material for making maltose and as an adhesive for paper products.

Starch is stored in granules, wherein each plant species' starch grains vary in structure, shape, and size [4-5]. The presence of starch is significant in the food industry, where the size and shape of the starch granules determine the function and use [6]. Also, starch grains' shape, type, and size can be used as a plant taxonomic character [7-8]. Most tubers store food reserves in the form of starch in the tubers, one of which is the yam plant. *Uwi* (yam), better known as *Dioscorea alata*, is one of the root crops of the Dioscoreaceae family, widely used as a carbohydrate source.

How to cite:
Sinay H, Karuwal RL, et al. (2024) Characterization of Starch Granule of Local Water Yam (*Dioscorea alata* L.) from Lermatang, Tanimbar Island District, Maluku. Journal of Tropical Life Science 14 (1): 187 – 194. doi: 10.11594/jtls.14.01.18.

Water yam has become the main farming commodity in Lermatang village, Tanimbar Islands Regency, Maluku. Until now, the cultivation of *uwi* plants in this area has still been traditionally done on rain-fed dry land. The *uwi* plant has the advantage of being easy to grow in various habitats, easy to care for, and adapted for cultivation in various environmental conditions [10]. The harvested *uwi* is usually used for own consumption or sale. The *uwi* is either boiled, fried, or roasted. A study shows that information on starch grains can be used as a reference in selecting tubers with high starch as an alternative food [11]. However, the limited and traditional use of yam restricts the further development of *uwi* as an alternative food, especially the starch granule-based yam.

Several studies on the characteristics of starch granules in various types of root crops examined the shape, type, and size of starch grains in *gembili*, *porang*, *uwi*, and *ganyong* [12-13], *uwi*, *gembili*, *gembolo*, *gadung*, and *tomboreso* [6][14]. While the yams found in Lermatang village, Tanimbar district, Maluku, were diverse, there is yet to be any report on the characteristics of their starch granules. The characteristics of starch grains yield pertinent information on the development and utilization of local accession for the food industry and as food ingredients for people. Therefore, a study on the characteristics of starch granules of the various yam accessions in this area may prove useful in deciding the further development of this commodity. Hence, this study was done to identify the characteristics of starch granules of various accessions of yam cultivated by the local community.

Material and Methods

The plant material used in this study were tubers from 6 accessions of yam (namely *Akiakab*, *Uwi Gula*, *Uwi Merah*, *Uwi Babulu*, *Uwi Petatas*, and *Uwi Pingingsian*) cultivated by farmers in Lermatang village, Tanimbar Islands Regency. The activity of describing the morphology of tubers using the Descriptor for Yam from the International Plant Genetic Resources Institute [15].

Observation of starch grain was conducted by using the fresh section method as proposed by Kumalawati *et al.* [13]. The preparation was started by cleaning the tuber sample, cutting the tuber, and then piercing the tuber with a toothpick until the parenchyma cells burst and produced liquid. The cell fluid was then transferred to an object glass that had been dripped with water, and the preparations were closed using a cover glass, coated with nail polish around the cover glass, and labeled.

The preparations were observed under a microscope using a magnification of 400× for the appearance of starch grains, while for the observation of the hilus type, using a magnification of 1000×. The results of the observations were photographed using an OptiLab camera connected to a computer, then observed the shape of the starch grains, the type of hilus, and the size and diameter of the starch grains. Measuring the diameter of starch grains using the measure feature in Image Ruster Software. Diameter measurements were carried out in 10 fields of view from 5 replicates for each yam accession. Starch grain diameter sizes were classified according to Lindeboom *et al*. [16] with very small categories (< 5 µm), small (5-10 µm), medium (10-25 µm), and large (> 25 µm). Starch grain characteristics include shape, and hilus type is described based on the appearance obtained. In contrast, the starch grain diameter size data is the average of observations results for ten fields of view from 5 replications.

Results and Discussion

Morphological description of yam accession

The results of field observations found six accessions of yam that are still cultivated by the community in Lermatang Village, namely: *uwi petatas, uwi pingingsian, uwi merah, uwi gula, uwi babulu*, and *uwi akiakap*, all of which are species of *D. alata* L. commonly used by farmers in Lermatang village, Tanimbar Islands Regency, Maluku. The following is a morphological variation of tubers from the six accessions (Figure 1), and a description of tuber morphology from each accession is presented in (Table 1).

Based on Figure 1 and Table 1, it can be seen that the morphology of the tubers found in Lermatang village, Tanimbar Islands, generally varies based on the shape and color of the tubers. The shape of the tubers varies from oval, cylindrical, and flattened to irregular shapes, with tuber colors varying from off-white and yellowish to white with purple spots. This is in line with the results of Fauziah & Mas'udah [17], Trimanto & Hapsari [18], and Purnomo *et al*. [19], which stated that tubers' shape and color in samples from several regions in Indonesia, such as Sumatra, Kalimantan,

Sulawesi, Java Island were generally oval, cylindrical, to irregular shape with tuber colors ranging from white, off white, purplish white, to purple. The emergence of morphological variations of various accessions of yam may be due to the influence of environmental factors. The same plant

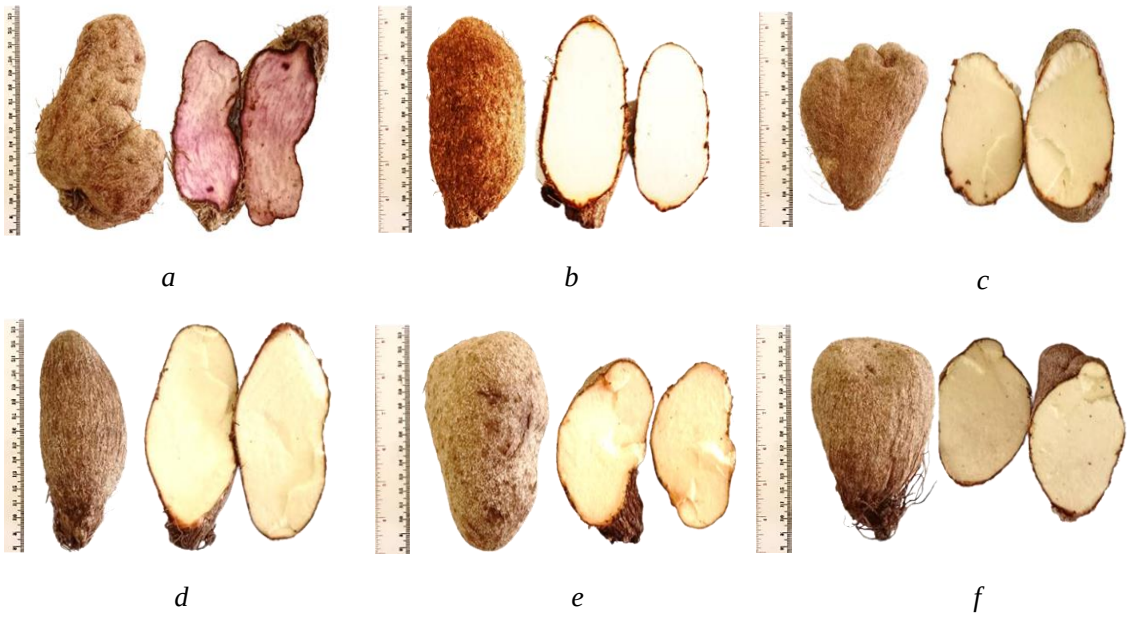

Figure 1. Morphological variation of Yam accession from Lermatang Village, Tanimbar Island. (a). *Uwi Merah,* (b). *Uwi Gula*, (c). *Uwi Pingingsian*, (d). *Uwi Babulu,* (e). *Uwi Akiakab*, and (f). *Uwi Petatas.*

Tabel 1. Morphological description of Yam accession from Lermatang Village, Tanimbar Island

No.	Local Name of Yam Accession	Shape	Tuber flesh color	Outer skin color	Inner skin color	Skin texture
1	*Uwi Merah*	irregular, length < 20 cm	white with purple	Brown	Purple	hairs at the base and middle, wrinkled, no blisters and cracks, and rough texture
2	*Uwi Gula*	cylindrical, < 20 cm in length	off white - yellowish	Brown	Light brown	hairs all over the surface, no wrinkles, no blisters and cracks, and a rough texture
3	*Uwi Pingingsian*	Oval - (flattened), < 20 cm in length	off white - yellowish	Brown	Light brown	hairs at the base and middle, wrinkled, no blisters and cracks, and rough texture
4	*Uwi Babulu*	cylindrical, < 20 cm in length	yellowish	Brown	Light brown	There are hairs all over the surface, wrinkled, with no blisters, no cracks, and a rough texture
5	*Uwi Akiakab*	Oval, < 20 cm in length	yellowish	Brown	Light brown	hairs at the base and middle, wrinkled, no blisters and cracks, and rough texture
6	*Uwi Petatas*	Oval, < 20 cm in length	yellowish	Brown	Light brown	hair at the base, wrinkled, no blisters and cracks, and a rough texture

species will show different morphological variations if environmental factors are more dominant than genetic ones, where differences influence phenotypic expression in environmental conditions [20-21].

Characteristic of a starch granule of yam accession

The results of observations of starch grain shape and hilus type in the six accessions showed variations in starch grain shape and hilus type. Variations in shape, size, and type of hilus appeared between each accession and within one accession (Figure 2).

Figure 2 shows that the shape of starch grains found in the six accessions of sweet potato was triangular (triangle), polygonal, circular (round shape), oval, and elliptical. However, the most dominant starch grain shapes in the six yam types were triangular, oval, and ellipse.

The form of starch granules obtained in this study aligns with the results of Otegbayo *et al*. [22], which showed that *D. alata* from Nigeria was generally circular, oval, and triangular. However, their report contrasted with another study by Fauziah *et al*. [6], which documented that the *D. alata* starch granules from East Java were predominately triangular and polygonal. Riley *et al*. [23] stated that *D. alata* from Jamaica showed starch grain of a variety of shapes such as ellipsoid, triangular, polyhedral, and rod-like shapes. Hence, the study found that the Lermatang village starch granules were comparable to that reported by Otegbayo *et al*. [22].

Based on Table 2, it can be seen that the size of starch granules varied from 44.98 ± 16.11 µm - 57.5 ± 11.86 µm, where the accession with the largest size was *Uwi Petatas* (57.5 µm ± 11.86). According to Lindeboom [16], this size fits into the "large" category of starch granules (> 25 µm). The average size of starch granule diameter in these six accessions was greater than those reported by Fauziah *et al*. [6], Nadia *et al.* [24], Otegbayo *et al*. [22], and Riley *et al*. [23], which average diameter was between 10-40 µm. Our result also corroborated the findings by Ahmad *et al*. [25], which stated that, generally, starch in tubers tends to be large.

Several studies reported that large starch grains have high viscosity, faster swelling, lower gelatinization temperature, and high water absorption ability. So, it can be used as a raw material to manufacture food products and for industrial applications [22,26,27].

There are variations in the shape and size of these starch granules depending on the starch source, plant growth conditions, and the harvest period of each plant [6]. According to Jiang *et al*. [28], the varying shape of starch granules in each accession might be due to plants' physical and chemical factors, physical properties of chloroplasts, light transmission, and their amylose

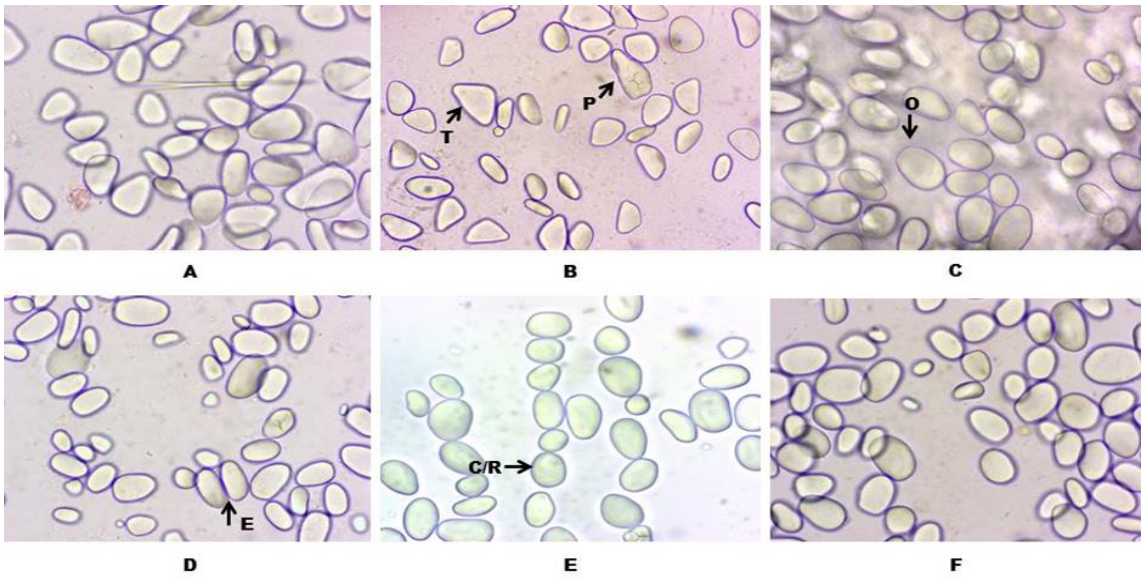

Figure 2. Variation of a starch granule of six yam accession from Lermatang A. *uwi Merah*, B. *uwi Gula*, C. *uwi Pingingsian*, D. *uwi Babulu*, E. *uwi Akiakab*, F. *Uwi Petatas* (Magnification 400x) (T: *Triangular*, P: Polygonal, O: Oval, E: *Ellips*, C/R: *Circular-round*).

Table 2. Characteristic of a starch granule of six yam accession from Lermatang

No.	Name of local accession	Average diameter of starch granule (µm)	Shape of starch granules	Hilus type	Category
1	*Uwi Merah*	53,8 ± 6,38	Triangular, polygonal, ellipse	Eccentric	Large
2	*Uwi Gula*	45,48 ± 9,22	Triangular, polygonal, ellipse	Eccentric	Large
3	*Uwi Pingingsian*	51,6 ± 4,43	Triangular, oval, ellipse	Eccentric	Large
4	*Uwi Babulu*	56,0 ± 5,25	Triangular, circular oval, ellipse	Concentric	Large
5	*Uwi Akiakab*	44,98 ± 16,11	Triangular, polygonal, oval, ellipse, circular	Concentric	Large
6	*Uwi Petatas*	57,5 ± 11,86	Triangular, oval, ellipse, circular	Eccentric	Large

contents.

In addition, the varying shape and size of each accession might be due to environmental factors [29]. These differences could affect the functional properties of starch itself when used as a food ingredient and as a raw material for non-food industries. The literature described that the shape and size of starch granules determine the final mesh size for purification applications and filters [6][30].

Variations in the shape of starch granules and in the hilus type are also shown. The hilus is the starting point where starch grains are formed, where the lamellae are fine lines surrounding the hilus [22,27]. Kumalawati *et al*. [13] also stated that starch granules are distinguished based on the location of the hilus, namely concentric and eccentric. The concentric type is where the hilus is in the middle, while the eccentric type is when the hilus is at the edge. However, Pei-Ling *et al*. [31] stated that the concentric hilus is not only a point in the middle but can be a straight line, a shape like a cleavage (cleft), dividing the granule into two shapes, namely a shape like a letter X or the letter Y. In contrast, Fatokun [4] stated that dry starch grains could cause fissures or cracks in the hilus to give a shape that looks like a double slit (stellate) called compound hilus.

The results of this study indicate that the *Akiakab* and *Babulu* have concentric hilus types with a compound shape of lines, Y, and Y compound (Figure 3a-c). Meanwhile, the lamellae are not visible. The other four accessions, namely *uwi Gula*, *Pingingsian, Petatas,* and *Merah*, were eccentric hilus types, revealing a compound Y-shaped hilus (Figure 4c). The hilus is not visible due to the lamellae arrangement. Thus, it can be assumed that the hilus type is eccentric, edge-type, usually sited at the top or tip of the starch grain. The presence of compound Y hilus can affect the starch granules' shape, which could be irregular or polyhedral (Figure 3c and 4c).

Starch granule shape, hilus type, and starch granule diameter in the six accessions tested in this study differed between each accession and within one accession. Our findings concurred with a report by Fauziah *et al*. [6], which stated that Dioscorea has a diversity of starch grains. The differences occurred between species and within one species, where the grains exist in different sizes and shapes.

A plant's genetic composition strongly influences starch grains' morphology, but the shape and size can change due to environmental influences. Starch grains in the same plant can vary between the organs in which the starch grains are deposited and the plant's age. Plants with enough nutrients for growth and development will produce larger starch grains, while those lacking nutrients or living in dry areas produce smaller grains [22,27]. Interestingly, the large starch grains in yam samples from Lermatang village are very good for industrial use, thus highlighting their potential for future development as a food source and for industrial applications.

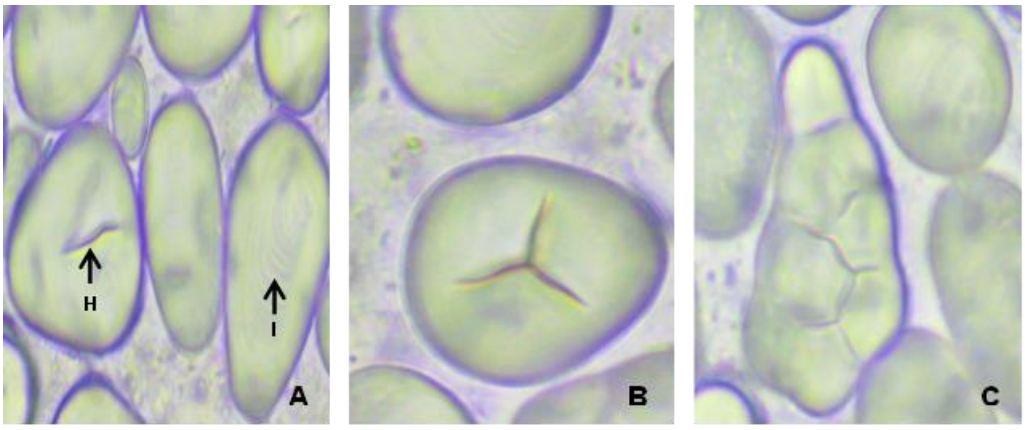

Figure 3. Type of concentric hilus with various shapes: Line, B. Y, and C.Y Compound (Magnification 1000x). H : Hilus, L (Lamellae).

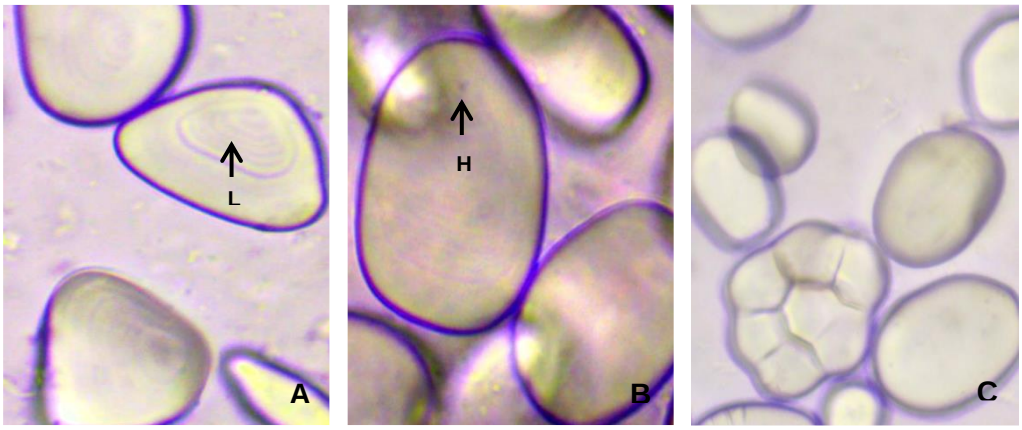

Figure 4. Type of eccentric hilus with various shapes: A-B. The point, and C.Y Compound (Magnification 1000×). H (Hilus), L (Lamellae).

Conclusion

Based on the result of this research, it can be concluded that Morphological characterizations of six accessions of *D. alata* from Lermatang, Tanimbar Islands, show variation in shape and color. The starch granules of *D. alata* of each accession varied in terms of granule shape and hilus type. The shape of starch granules is dominated by triangular, oval, and elliptical shapes, with large granule size categories and eccentric and concentric hilus types. Large starch granules in each accession of *D. alata* can be recommended to develop food potential such as filler, binder, thickener, gelling agent, emulsifier, encapsulation, edible film, texture forming, and stabilizing agent.

Acknowledgments

The author would like to thank Brawijaya University for financially supporting this work through Professor Research Grant.

References

1. Xiao H, Wang S, Xu W, et al. (2020) The study on starch granules by using darkfield and polarized light microscopy. Journal of Food Composition and Analysis 92(103576): 1-7. doi: 10.1016/j.jfca.2020.103576.
2. Chakraborty I, Pallen S, Shetty Y, et al. (2020) Advanced microscopy techniques for revealing molecular structure of starch granules. Biophysics Review 12(1): 105–122. doi: 10.1007/s12551-020-00614-7.
3. Schwartz D, Whistler RL (2009) In: BeMiller JN, Whistler R(eds) Starch: chemistry and technology, 3rd edn. Academic Press, New York.
4. Fatokun OT (2019) Micrometrics and morphological properties of starch. In (Ed.), Chemical Properties of Starch. IntechOpen. doi: 10.5772/inte-chopen.90286.
5. Sundarram A, Murthy TPK (2014) α-Amylase production and applications review. Journal of Application and Environmental Microbiology 2(4): 166-175. doi: 10.12691/jaem-2-4-10.
6. Fauziah, Mas'udah S, Hendrian (2016) Study on the starch granules morphology of local varieties of *Di-*

oscorea hispida and *Dioscorea alata*. The Journal of Tropical Life Science 6(1): 47-52. doi: 10.11594/jtls.06.01.09.
7. Hidayat EB (1995) Anatomi Tumbuhan Berbiji. Jurusan Biologi FMIPA ITB, Bandung.
8. Susetyarini E, Wahyono P, Latifa R, Nurrohman E (2019) The identification of morphological and anatomical structures of *Pluchea indica*. The 5th Hamzanwadi International Conference of Technology and Education 2019 Journal of Physics: Conference Series. 1539 (2020) 012001IOP Publishing. doi:10.1088/1742-6596/1539/1/012001.
9. Bertoft E (2017) Understanding starch structure: Recent Progress. Agronomy 7(56): 1-19. doi: 10.3390/agronomy7030056.
10. Adjei EA, Esuma W, Alicai T, et al. (2022) Genotype-by environmenti interaction of yam (*Dioscorea species*) for yam mosaic virus resistance, dry matter content and yield in Uganda. Agronomy 12(9): 1-20. doi: 10.3390/agronomy12091984
11. Cornejo-Ramírez YI, Martínez-Cruz O, Del Toro-Sánchez CL, et al. (2018) The structural characteristics of starches and their functional properties, CyTA - Journal of Food 16(1): 1003-1017. doi: 10.1080/19476337.2018.1518343.
12. Richana N, Sunarti TC (2004) Karakterisasi sifat fisikokimia tepung umbi dan tepung pati dari umbi ganyong, suweg, ubi kelapa, dan gembili. Jurnal Biotropika, 5(1): 29-37. doi: 10.21082/jpasca.v1n1.2004.29-37.
13. Kumalawati H, Izzati M, Widodo S, Suedy A (2018) Bentuk, tipe dan ukuran amilum Umbi Gadung, Gembili, Uwi Ungu, Porang dan Rimpang Ganyong. Buletin Anatomi dan Fisiologi 3(1): 56-61. doi: 10.14710/baf.3.1.2018.56-61.
14. Purnomo, Suharyanto, Wardana H (2009) Kekerabatan Fenetik *Dioscorea spp*. Berdasarkan Karakter Anatomi Umbi. Berkala Ilmiah Biologi 8(2): 41-49.
15. IPGRI/IITA (1997) Descriptors for Yam (*Dioscorea* spp.). International Institute of Tropical Agriculture, Ibadan, Nigeria/International Plant Genetic Resources Institute, Rome, Italy.
16. Lindeboom N, Chang PR, Tyler RT (2004) Analytical biochemical and physicochemical aspects of starch granule size with emphasis on small granule starches. Starch/Stärke 56(3-4): 89–99. doi: 10.1002/star.200300218.
17. Fauziah, Mas'udah S (2015) Explorations diversity of *Dioscorea spp*. varieties from Pasuruan, East Java: Inventory and characterization. Agrivita Journal of Agricultural Science 37(3): 193–203. doi: 10.17503/Agrivita-2015-37- 3-p193-203.
18. Trimanto, Hapsari L (2015) Diversity and utilization of *Dioscorea spp*. tuber as alternative food source in Nganjuk Regency, East Java. AGRIVITA Journal of Agricultural Science 37(2): 97–107. doi: 10.17503/Agrivita-2015-37-2-p097-107.
19. Purnomo, Daryono BS, Rugayah, et al. (2016) Genetic variability and classification of Indonesian yams (*Dioscorea spp*.) based on RAPD analysis. Sabrao Journal of Breeding and Genetics 48(4): 377– 390.
20. Hoffmann AA, Shirriffs J, Scott M (2005) Relative importance of plastic vs genetic factors in adaptive differentiation: geographical variation for stress resistance in Drosophila melanogaster from eastern Australia. Functional Ecology 19: 222–227. doi: 10.1111/j.1365-2435.2005.00959.
21. Andrew RI, Wallis IR, Harwood CE, Foley WJ (2010) Genetic and environmental contributions to variation and population divergence in a broad-spectrum foliar defence of *Eucalyptus tricarpa*. Annals of Botany 105: 707–717. doi: 10.1093/aob/mcq034.
22. Otegbayo B, Oguniyan D, Akinwumi O (2013) Physicochemical and functional characterization of yam starch for potential industrial applications. Starch/Stärke 65(1): 1-16. doi: 10.1002/star.201300056.
23. Riley CK, Wheatley AO, Asemota HN (2006) Isolation and characterization of starches from eight *Dioscorea alata* cultivars grown in Jamaica. African Journal of Biotechnology 5 (17): 1528-1536. doi: 10.5897/AJB06.388.
24. Nadia L, Wirakartakusuma MA, Andarwulan N, Purnomo EH, et al. (2014) Characterization of physicochemical and functional properties of starch from five yam (*Dioscorea alata*) cultivars in Indonesia. International Journal of Chemical Enginering and App 5(6): 489-496. doi: 10.7763/IJCEA.2014.V5.434.
25. Ahmad J, Tiwari BK, Imam SH, Rao MA (2012) Starch-based polimeric materials and nanocomosites. CRC Press. United States of America.
26. Jayeola AA, Akinsebikan OA (2013) Micromorphological studies of starch granules in selected processed indigenous flour of South Western Nigeria. Timişoara ser. Bio XV (1): 1-10.
27. Tanimola AR, Otegbayo BO, Akinoso R (2022) Physicochemical properties of yam starches from fifty-five lines of Dioscorea species. Food Research 6(3): 49-61. doi: 10.26656/fr.2017.6(3).224.
28. Jiang Q, Gao W, Li X, et al. (2012) Characterizations of starches isolated from five different Dioscorea species. Food Hydrocolloids 29: 35-41. doi: 10.1016/j.foodhyd.2012.01.011.
29. Copeland L, Balazek J, Salman H, Tang MC (2009) Form and functionality of starch. Food Hydrocolloid 23: 1527-1534. doi: 10.1016/j.foodhyd.2008.09.016.

30. Leonel M, Sarmento SBS, Cereda MP (2003) New starches for the food industry: *Curcuma longa* and *Curcuma zedoaria.* Carbohydrate Polymers 54: 385-388. doi: 10.1016/S0144-8617(03)00179-6.

31. Pei-Ling L, Xiao-Song H, Qun S (2010. Effect of high hydrostatic pressure on starches: A review. Starch Biosinthesis, Nutrition, and Biomedhical 62(12): 615-628. doi: 10.1002/star.201000001.