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Diversity of 17 Genotypes of Taro Based on Anatomy and Nutritional Value of Tuber

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ABSTRACT

Indonesia is one of the countries with the greatest diversity of taro variety, while the study of taro's morphology and nutritional characteristics is limited. The aim of this study was to evaluate the anatomical of plant and nutritional value of taro tuber. This research observed fourteen genotypes of *Colacasia esculenta* (7 Eddoe types, 7 Dasheen types) and 3 *Xanthosoma* genotypes. In three blocks of replications, the eddoe and *Xanthosoma* genotypes were cultivated using cormel and the dasheen genotypes with sucker. Plant anatomy (leaf, stem, and root) and tuber nutritional characteristics were analyzed. From this research, explained that stomata and epidermis number, length from stomata and epidermis, number leaf epidermis, length of leaf and stem epidermis, also length of root epidermis, endodermis, cortex, and stele among 17 genotypes of taro were statistically different. The diversity of taro based on the nutrition content of tuber between 17 genotypes of taro was considered high, as represented by water, ash, fat, protein, carbohydrate, energy, and glucomannan, which were statistically different.

1. Introduction

Taro knowing as tropical root crop and part of the Araceae family. The Araceae family has several subfamilies on different of habitats, disposition, and morphology of leaf, including structure of inflorescence and pollen, morphology and anatomy of flower, also number of chromosome (Grayun 1990). Indonesia has largest diversity of taro, ranging from wild taro to cultivated and commercial taro, with the cultivation of at least 40 cultivars in various regions, i.e., Java, Kalimantan, and Sulawesi to Papua, Indonesia (Mulyaningsih *et al.* 2019). The diversity of taro genotypes are almost found in all islands of Indonesian archipelago with different local names (Maretta *et al.* 2022). Term of "taro' frequently used for four aroid species: *Alocasia macrorrhiza* (L.) G.Don (knowing as giant taro), *Colocasia esculenta* (knowing as taro, true or ordinary taro), *Cyrtosperma merkusii* (Hassk.) Schott (knowing as giant swamp taro) and *Xanthosoma sagittifolium* (L.) Schott (knowing as cocoyam, tania, taro Fiji) (Mergedus *et al.* 2015), however, *Colocasia esculenta* var esculenta (dasheen type), and *Colocasia esculenta* var. antiquorum (eddoe type) were widely cultivated and consumed. Dasheen type identified from its large central corm, following with suckers and stolons, while eddoe type, has a small central corm and a large number of smaller cormels (Mergedus *et al.* 2015; Banjaw 2017).

Taro is an important food in several countries in the humid tropics and subtropics area (Chaïr*et al.* 2016). Tubers of taro, nutritionally, has potential to provide economical sources of dietary energy in the form of carbohydrates. Leaves and petioles of taro also promising source of carbohydrates, protein, vitamins A and C, calcium, phosphorus, and potassium (Pitoyo *et al.* 2018). The proximate content of the taro tuber fresh weight includes moisture 63-85%, crude fiber 0.60-1.18%, ash 0.60-1.3%, vitamin C 7-9 mg/100 g, thiamine 0.18 mg/100 g, riboflavin 0.04 mg/100 g, and niacin 0.9 mg/100g (Pe *et al.* 2015). Previous research reported tha the leaves of taro were has ash (10.00%), crude fiber (16.27%), fat (10.17%), and protein (29.41%) contents (Eleojo *et al.* 2020).

However, the success of a crop's genetic improvement through a plant breeding program is depends on the availability of genetic resources

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diversity (Okpul *et al.* 2004). Morphological analysis knowing as traditional technique that used to know genetic variation within species referring to the differences of morphology and anatomy (Acquah 2012). Both quantitative and qualitative morphological variation of taro, might contribute desirable character, and included in plant breeding development. Anatomical character research also has a very important aspect as the parameter to determine the diversity level in taro. Morphology characteristic is often used to represent and identify intra-species with phenotypic variation because it is fast, simple, also inexpensive (Jingura and Kamusoko 2015; Suratman *et al.* 2016), while research about plant characteristic of anatomy is also useful for systematic study, species identification, and solving the taxonomic problem (Chikmawati 2013).

Studying the characteristics and knowledge about variability among the genotypes of taro helps to develop conservation and plant breeding strategies for improvements and utilization of the resources in advance (Banjaw 2017). In Indonesia, the study of taro's morphology and nutritional characteristics is limited. The aim of this research was to evaluate the plant anatomy and nutritional value the tuber of taro.

2. Materials and Methods

2.1. Planting Methods

The research was done from October 2020 to May 2021, located at experimental field of Study Program of Agrotechnology, Darussalam Gontor University at Sub-district Demangan District Siman Ponorogo, East Java. Fourteen *C. esculenta* genotypes were used in the study, consisting of 7 eddoe types (satoimo, ozikawa, siromi, jepang hijau, jepang ungu, dempel, and dempel ungu), 7 dasheen types (california, pratama, ketan, bentul, bentul ungu, pari, and sutra), and 3 *Xanthosoma* genotypes (talas hijau, talas kuning and talas hitam).

The eddoe types were cultivated using cormel as a plant material, whereas dasheen types and *Xanthosoma* genotypes were cultivated with sucker. All genotypes were planted in 3 blocks. Ten plants from each genotype was planted in each block. The soil was plowed and harrowed twice before planting. A raised bed about 30 cm from the soil level was designed for the planting site, and each bed only planted a single line. The width of the planting bed was one meter. Planting distance is applied at 100 cm among genotype and 60 cm in a row among genotype. A single cormlet was used In each planting hole.

2.2. Plant Anatomy Analysis

2.2.1. Stomata and Leaf Anatomy Analysis

Observations were conducted at the Central Laboratory Faculty of Sains and Technology of Darussalam Gontor University, Ponorogo.

Stomata collection was carried out in the morning at 09.00-10.00 when the plant leaves received sunlight so that the stomata had fully opened. The leaves of the sample on the adaxial and abaxial surfaces were cleaned with a tissue to remove dust/dirt from the leaves, and then, the sample of leaves smeared with nail polish, left for 10 minutes, following by the dried pasted with insulation and leveled, furthermore, the insulation is peeled off and taken slowly, then affixed to the glass slide and labeled with a description of the type of taro plant genotype.

Observations made for one field of view with a magnification of 400x include the number of epidermal cells and number of open stomata was done with three repetitions. The number of open stomata was counted in one field of view, then, the epidermal and stomata cell length was also observed. Measurements are based on the longest side of the cell using the Image raster type 3.0 program (Anu *et al.* 2017) with 3 repetitions 4) Calculation of stomata index and stomatal density is carried out using the following formula:

$$\text{Index of stomata} = \frac{\text{number of stomata}}{\text{number of stomata + number of epidermal}} \times 100$$

$$\text{density of stomata} = \frac{\text{number of stomata}}{\text{Large of area field view}}$$

Leaf anatomy analysis was done by taking the leaf pieces of taro, manually sectioned transversely with a razor blade, approximately 1x1 cm from mid position. Samples were then placed on a glass object and observed under a microscope. Stomata and leaf anatomy were observed using a CX21FS1 series microscope with a magnification of (400x). The microscope is first connected to the Advance series Optilab. The Optilab cable is already connected to the laptop installed with the Image Raster application. Optilab will photograph the leaf anatomy structure, and the number and length of epidermal tissue measured sing Image Raster.

2.2.2. Stem and Root Anatomy Analysis

Stem and root anatomy analysis is made as non-permanent, with 3 replications for each genotype. Stem anatomy analysis includes the length of the epidermis, while root anatomy includes the root epidermis, endodermis, cortex, and stele of taro. Analysis was done destructively by pulling the plant, cleaning the stem and root from the soil with water, and then cutting the stem and root sample. The sample was then placed on a sliding glass. The sample was observed using a CX21FS1 series microscope with a magnification of (400x).Before taking measurements, the microscope is calibrated first. Steam and root anatomy were measured using Image Raster.

2.2.3. Proximate Analysis

Proximate analysis, including water content, ash, fat, protein, carbohydrates, and energy based on guidebook SNI-01-2891-1992, was done at the Indonesian Centre for Agricultural Post Harvest Research and Development Laboratory.

2.2.4. Glucomannan Analysis

Glucomannan analysis was done using the gravimetric method at the Indonesian Centre for Agricultural Post Harvest Research and Development Laboratory following Widjanarko and Megawati (2015) method.

2.3. Data Analysis

F test were using for analyzed the data, and means were compared by Duncan's Multiple Range Test (DMRT) at $\alpha = 5\%$.

3. Results

From the data in Table 1, it is known that among 17 genotypes, california and dempel had the highest number of leaf epidermis with 94.00, and was not significantly different with pari genotype by 91.67, while the lowest average number of the epidermis was in genotype talas kuning with 33.00 and not significantly different with siromi 38.00. Furthermore, it can be explained that the highest epidermal length was found in siromi at 39.70 µm and not significantly different from talas hijau at 37.46 µm, and the lowest epidermal length number was in california at 17.04 µm. Table 1 also explains that jepang hijau genotype has the longest stem epidermis of taro with 11.04 µm while the shortest was bentul ungu genotype with 5.68 µm. Overall, Figure 1 explain that there was significant different on stem anatomy among taro genotypes.

According to Figure 2, the taro stomata are anomocytic (irregular-celled), which means that the stoma is surrounded by a definite number of cells that are not different from the rest of the epidermis.

Data on the Table 2 explain that 17 genotypes of taro have significantly different on stomata number, density of stomata, and the stomata index. Dempel genotype has the highest number of stomata, but significantly was not different from bentul ungu, california, and sutra, meanwhile, the lowest average number of stomata was found at dempel ungu. On the other hand, dempel genotype has the highest density of stomata but is not significantly different from bentul ungu, california, and sutra. While on the index stomata parameter, it can be seen that talas kuning has the highest stomata, and is not significantly different from siromi, jepang ungu, bentul ungu, ketan, sutra, and talas hitam.

Data in Table 3 and Figure 3 explain that the highest average on length root epidermal variables among 17 genotypes was the talas hijau genotype with 26.03 µm was not significantly different from the california, ozikawa, sutra, talas hitam, and talas kuning genotypes. In contrast, the lowest average length root epidermal was the dempel ungu genotype with 11.27 µm. Furthermore, the genotype with the highest average

Table 1. Mean of length and number of epidermis of leaf, and length of stem epidermis of taro

Genotype	Leaf		Stem
	Number of epidermis	Length of epidermis (µm)	Length of epidermis (µm)
Satoimo	66.00 f	30.46 def	7.55 bcd
Ozikawa	48.33 cd	35.77 hi	6.21 ab
Siromi	38.00 ab	39.70 j	7.45 bcd
Jepang hijau	64.00 ef	31.16 efg	11.04 f
Jepang ungu	46.00 bc	33.05 fgh	8.97de
Dempel	94.00 h	24.19 b	8.15 cde
Dempel ungu	53.33 cd	32.86 fgh	9.39e
Bentul ungu	66.00 f	27.75 cd	5.68 a
Ketan	53.33 cd	32.06 fg	8.76 cde
Pratama	63.33 ef	26.45 bc	6.35 ab
California	94.00 h	17.04 a	6.06 ab
Pari	91.67 h	28.00 cde	9.53 e
Sutra	66.33 f	31.28 fg	7.95 cde
Bentul	80.67 g	31.29 efg	7.26 abc
Talas hitam	55.67 de	25.55 bc	5.96 ab
Talas hijau	47.00 cd	37.46 ij	7.18 abc
Talas kuning	33.00 a	34.54 ghi	8.16 cde
F value	40.919	25.803	9.324

Numbers followed by different letter in the same column indicate significant difference based on DMRT at α: 5%

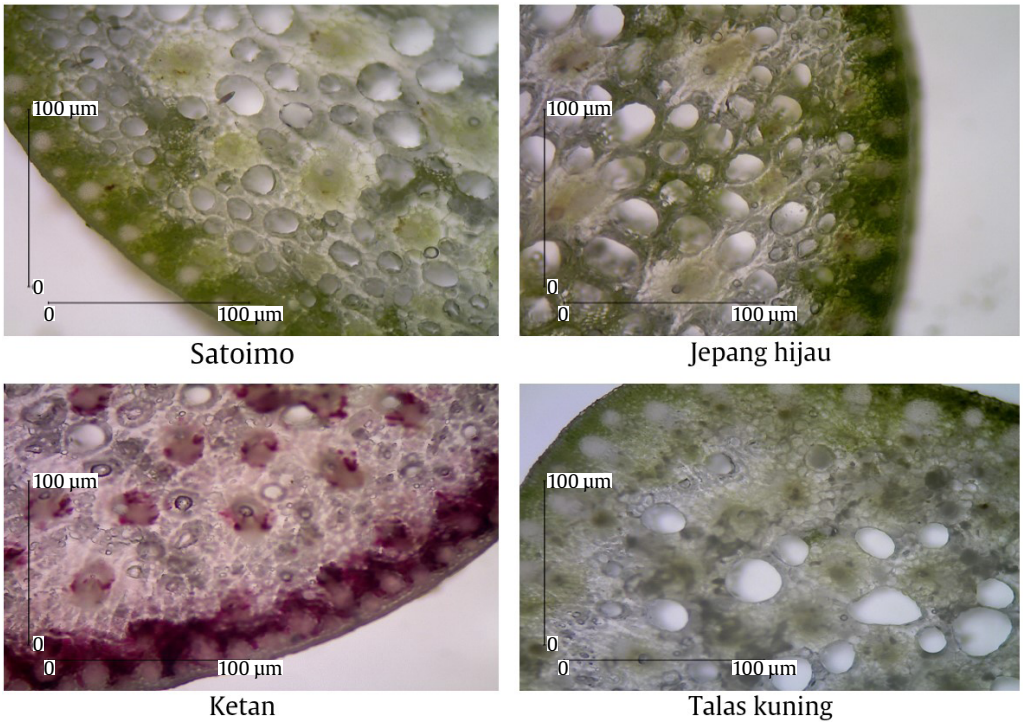

Figure 1. Characteristic of Petiole of Taro

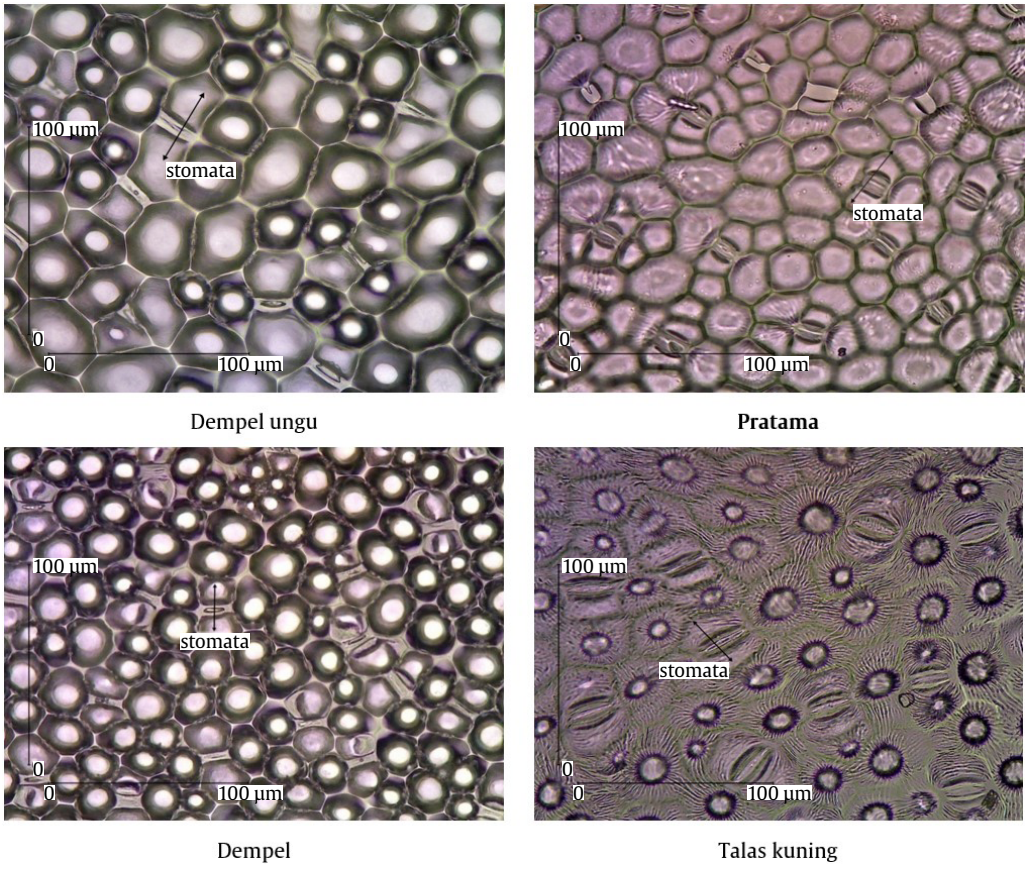

Figure 2. Characteristic of stomata of taro from abaxial surface

Table 2. Mean of number stomata, stomata index, and stomata density

Genotype	Number of stomata	Stomata density	Stomata index
Satoimo	9.00 abc	0.45 cde	13.52 cd
Ozikawa	8.33 ab	0.42 de	16.28 bcd
Siromi	9.00 abc	0.45 cde	22.69 ab
Jepang hijau	12.00 bcd	0.61 bcd	18.01 bcd
Jepang ungu	9.33 abc	0.47 cde	19.09 abc
Dempel	15.67e	0.79 a	16.07 bcd
Dempel ungu	7.33 a	0.37 e	13.05 cd
Bentul ungu	13.67 de	0.69 ab	19.32 abc
Ketan	10.67 abcd	0.54 bcde	19.15 abc
Pratama	11.33 bcd	0.57 bcd	16.99 bcd
California	12.67 cde	0.64 abc	12.87cd
Pari	8.67 ab	0.44 de	9.32 d
Sutra	13.67 de	0.69 ab	19.00 abc
Bentul	11.67 bcd	0.59 bcd	14.06 bcd
Talas hitam	11.00 abcd	0.56 bcde	19.06 abc
Talas hijau	8.33 ab	0.42 de	16.85 bcd
Talas kuning	9.33 abc	0.47 cde	26.7 a
F value	4.300	4.01	2.4

Numbers followed by different letter in the same column indicate significant difference based on DMRT at α: 5%

Table 3. Mean length of root epidermis, endodermis, korteks and stele of taro (µm)

Genotype	Epidermis	Endodermis	Cortex	Stele
Satoimo	20.23 cdef	17.69 cde	20.25 bc	54.71 de
Ozikawa	21.44 defg	22.80 fg	30.40 g	59.10 f
Siromi	15.96 abc	24.09 gh	17.85 b	41.97 b
Jepang hijau	16.49 bcd	18.32 cdef	20.99 bc	66.50 h
Jepang ungu	15.18 abc	10.25 a	29.81 g	33.43 a
Dempel	17.97 bcde	20.27 defg	24.98 de	42.59 bc
Dempel ungu	11.27 a	10.32 a	25.17 de	54.48 de
Bentul ungu	17.79 bcde	11.91 ab	29.57 fg	60.22 f
Ketan	19.9 cdef	12.45 ab	31.07 g	65.69 gh
Pratama	20.15 cdef	23.10 fg	32.63 g	58.42 ef
California	21.26 defg	16.58 bcde	31.48 g	66.38 h
Pari	13.24 ab	17.78 cde	25.63 def	51.08 d
Sutra	21.93 efg	14.87 abc	29.55 fg	46.00 c
Bentul	17.78 bcde	15.38 bcd	22.87 cd	62.19 fg
Talas hitam	22.74 efg	10.31 a	12.94 a	69.61 h
Talas hijau	26.03 g	28.42 h	28.90 efg	89.34 j
Talas kuning	24.34 fg	20.80 efg	32.62 g	84.00 i
F value	6.607	12.421	19.393	119.089

Numbers followed by different letter in the same column indicate significant difference based on DMRT at α: 5%

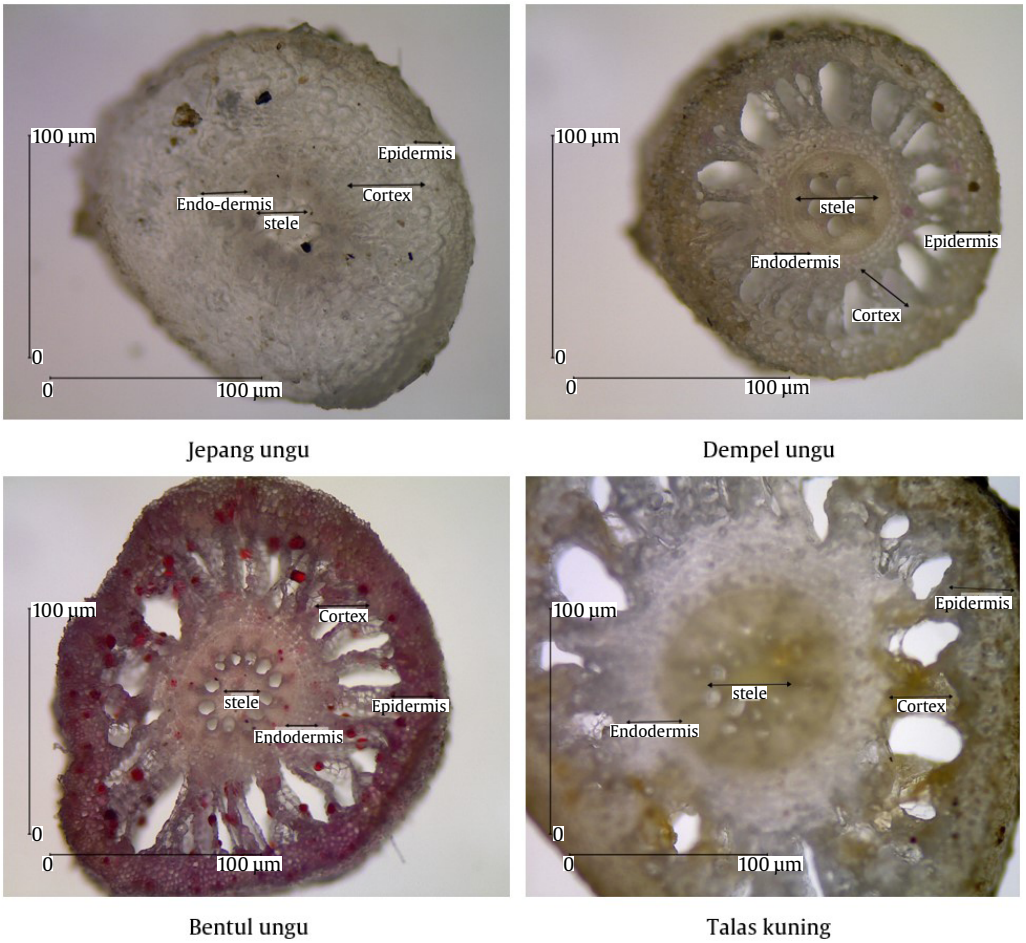

Figure 3.Characteristic of root of taro

of root endodermis was the talas hijau genotype, with 28.4 µm but was not significantly different from siromi genotype, and the lowest average was 10.25 µm in the jepang ungu genotype. For the length of cortex parameter, from the table above known that pratama genotype has the longest cortex among 17 genotypes with 32.63 µm but was not significantly different with talas kuning, talas hijau, sutra, california ketan, bentul ungu, jepang ungu and ozikawa genotype, while the lowest average of length root epidermal was talas hitam genotype with 12.94 µm. Data in Table 3 also explain that talas hijau genotype has the longest root stele parameter with 89.34 µm, while jepang ungu has the shortest root stele with 33.43 µm. The cortex consists of parenchymatic tissue characterized by intercellular spaces.

3.1. Proximate Content of Corm of Taro

Table 4 showed that the highest water content between the corm of 17 genotypes of taro was satoimo genotype with 88.80%. The lowest water content was talas hitam, with 59.46%, while the highest ash content variable from the 17 genotypes of taro was in the genotype pratama with 1.247% but was not significantly different from the genotypes jepang ungu and pari, with the lowest average of ash value was in genotype dempel ungu with 0.280%, Data in Table 1 also explains that the highest fat variable in the 17 genotypes of taro was in the genotype jepanghijau by 0.757%, but was not significantly different from the genotype california, while the lowest average fat number was in the genotype ketan by 0.263%. Furthermore, it can be seen that the highest protein content among 17 genotypes was in the genotype talas kuning, by 2.840%, but was not significantly different from the bentul ungu genotype, while the lowest average protein number was in the genotype dempel with 1.737%. Table 4 also shows that the highest carbohydrate variable among 17 genotypes was in the genotype talas hitam, with 37.15%, and the lowest average carbohydrate number was in the satoimo genotype with 7.84%. Furthermore, the data above showed that the highest energy content between 17 genotypes was in the talas hitam genotype with 159.50 kcal and the lowest average energy number was in the treatment of the genotype satoimo with 43.63 kcal.

3.2. Glucomanan Content of Corm of Taro

From the data in Table 5, it can be seen that the highest glucomannan weight among the 17 genotypes was genotype talas hitam with 0.099 g. The lowest average glucomannan weight was in ozikawa genotype with 0.002 g, while the highest percentage of glucomannan between 17 genotypes

Table 4. The mean of proximate content of corm of the taro

Genotype	Water (%)	Ash (%)	Fat (%)	Protein (%)	Carbohydrate (%)	Energy (kcal)
Satoimo	88.80 l	0.66 d	0.673 i	2.017 bc	7.84 a	43.63 a
Ozikawa	86.92 k	0.46 b	0.590 gh	2.313 ef	9.71 b	51.45 b
Siromi	83.83 j	0.847e	0.317abc	2.510 f	12.50 c	60.78 c
Jepang hijau	79.21 i	0.780 e	0.757 j	2.253 de	17.00 d	81.71 d
Jepang ungu	72.17 g	1.197 i	0.347 cd	2.330 ef	23.96 f	105.38 f
Dempel	67.62 e	0.967 f	0.567 gh	1.737 a	29.11 h	126.27 h
Dempel ungu	76.21 h	0.280 a	0.280 ab	1.753 a	21.48 e	94.89 e
Bentul ungu	66.45 d	1.083gh	0.343cd	2.760 g	29.37 h	129.85 h
Ketan	69.72 f	0.597 cd	0.263 a	1.843 ab	27.58 g	118.10 g
Pratama	72.17 g	1.247 i	0.607 h	1.777 a	24.20 f	107.14 f
California	63.70 c	1.03 fg	0.723 ij	2.243 de	32.30 i	141.95 i
Pari	61.33 b	1.147 hi	0.53 fg	1.770 a	35.22 j	151.28 j
Sutra	61.83 b	1.063 fgh	0.323 bc	2.220 de	34.69 j	147.47 ij
Bentul	84.44 j	0.477 b	0.587gh	1.880 abc	12.62 c	60.72 c
Talas hitam	59.46 a	0.540 bc	0.433 e	2.420 ef	37.15 k	159.50 k
Talas hijau	67.05 de	0.810 e	0.393 de	2.080 cd	29.67 h	128.32 h
Talas kuning	63.39 c	0.850 e	0.510 f	2.840 g	32.41 i	141.87 i
F value	1816.570	75.110	81.473	27.212	1286.353	220.441

Numbers followed by different letter in the same column indicate significant difference based on DMRT at α: 5%

Table 5. Mean of content of glucomanan of corm of taro

Genotype	Weight of glucomannan(g)	% glucomannan
Satoimo	0.009 a	2.76 defg
Ozikawa	0.002 a	3.29 abc
Siromi	0.007 a	2.50 fg
Jepang hijau	0.006 a	3.31 abc
Jepang ungu	0.005 a	3.36 ab
Dempel	0.007 a	2.34 g
Dempel ungu	0.009 a	3.19 bcd
Bentul ungu	0.023 b	2.80 cdefg
Ketan	0.012 ab	3.28 abcd
Pratama	0.005 a	3.36 ab
California	0.074 e	3.25 abcd
Pari	0.024 b	2.60 efg
Sutra	0.038 c	2.95 bcdef
Bentul	0.059 d	3.30 abc
Talas hitam	0.099 f	3.05 bcde
Talas hijau	0.072 e	3.26 abcd
Talas kuning	0.073 e	3.72 a
F value	54.065	5.00

Numbers followed by different letter in the same column indicate significant difference based on DMRT at α: 5%

was in talas kuning. The lowest average percentage of glucomannan was dempel genotype. In eddoe taro, glucomannan and oxalate content determined the quality of the cormels.

4. Discussion

According to the research on 17 genotypes, taro has a significantly different number of stomata, density of stomata, and index of stomata. Stomata characteristics vary greatly between plant species, including density, size, and shape (Hong *et al.* 2018). Stomata size, density, and distribution patterns differ significantly between species or genotypes within a species, providing genetic resources for selection (Jingjing and Yun-Kuan 2018). Stomata regulate the exchange of gases, particularly water vapor and CO_2, between the interior of the leaf and the surrounding environment. Plant transpiration is closely related to stomata density (Metusala *et al.* 2017). Stomata play important roles in transpiration and drought defense. Reduced stomata density affects plant defenses system against drought stress; on the other hand, reduced stomata density reduces water evaporation in plants by reducing the number of leaf pores (Wulandari *et al.* 2020).

The leaf anatomy of seventeen taro genotypes differs, including the length and number of epidermis. Leaf anatomical traits are important in plant functions and exhibit evolutionary adaptive changes to adapt to the surrounding environment. When it comes to responding to environmental conditions, the leaf is the most adaptable organ (Nevo *et al.* 2000; Marchi *et al.* 2008). The structures of leaf reflect the effects of drought stress clearly than stems and roots in drought stress condition. Data on various leaf anatomy characteristics indicated that there was enough room for selecting accessions based on these characteristics for genetic improvement (Suratman *et al.* 2016).

The data research show a significantly different variation among the genotypes of taro on root anatomy characters. Water transport capacity is one of the most functional aspects of root anatomy because the number and size of the water-conductive elements highly influence it. Root anatomical studies can provide valuable insight into plant breeding program related with the mechanical resistance to hydraulic flow within the root system (Valenzuela-Estrada *et al.* 2008). The significantly different variation among the genotypes on plant anatomy characters is a sign of the presence of a high degree of genetic variation, implying great potential for accessions in future breeding programs through selection (Nkansah *et al.* 2013; Roy *et al.* 2013; Sabaghnia *et al.* 2014).

Analysis of the tuber of 17 taro genotypes revealed a significant difference in proximate content, including carbohydrate, protein, ash, water, fat and energy. Protein not only important to the major physiological functions (tissue structure, enzymatic activities, hormones, antibodies), but also necessary for the growth and development of the body, including maintenance, healing and replacement of worn or damaged tissue, also production of metabolic and digestive enzymes. Corm of taro starch is easily digestible; the starch grains are fine and small; it is hypoallergenic; and it is gluten-free. Taro grown in different locations has varying carbohydrate content (Siskawardani *et al.* 2020).

The wide variations in chemical composition observed in different Colocasia cultivars may be due primarily to varietal differences, which ultimately determine the nutritional value of a particular crop, because all cultivars were grown under similar climate and soil type conditions, using uniform cultivation practices (Buragohain and Angami 2013). A food's energy value is the amount of energy that can be extracted from it during digestion. Kilojoules (KJ) or kilocalories (kcal) are the units of measurement.The

lipid, total sugar, and protein content of taro allowed us to calculate its energy value (Ouoba *et al.* 2022).

The glucomannan and proximate content of the taro tuber determine its quality. Taro's glucomannan content has been extensively researched (Njintang *et al.* 2011; Ekowati *et al.* 2015). According to the research, Talas Kuning has the highest glucomannan content. Glucomannan is a carbohydrate that is widely used in the beverage, food, and pharmaceutical industries (Santosa *et al.* 2011). Glucomannan was also investigated for health and beauty concerns due to its neutral, fermentable, and viscous dietary fiber, which has been approved to reduce obesity, relieve physiological disorders, particularly diabetes and cardiovascular disease, lower blood lipid and cholesterol (Wardani and Handrianto 2020), and extend frozen storage of processed meat and fish products.As a result, producing cormels with a high glucomannan content is desirable (Maretta *et al.* 2020).

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