Physico-chemical characteristics of elephant foot yam (Amorphophallus campanulatus) germplasm

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Abstract. The diversity of elephant food yam (Amorphophallus campanulatus) in Indonesia is essential to be explored concerning its potential use for food and benefit for health. Breeding for release new varieties with specific characters needs a various of genetic materials, particularly from germplasm collection. Therefore, this study was performed to identify the physicochemical characteristics of 14 elephant food yam germplasm collected by Indonesian Legumes and Tuber Crops Research Institute (ILETRI). The physical observations showed that the colour of the flesh varied from yellow to orange with the lightness values (L*) ranging from 70.53 to 81.63. The moisture, ash, reducing sugar, and amylose content also varied from 66.58 – 88.36 %, 2.49-4.91 % (dm), 1.42-7.89 % (dm), 23.84-31.37 % (dm), respectively. These elephant food yam genotypes particularly contained high dietary fiber with the highest value observed in MLGAR 0101 (54.29 % dm) and MLGAR 0016 (53.15 % dm). The hardness levels of the boiled tubers ranged from 11.90-38.1 N with the highest value observed in MLGAR 0131, suggesting that this genotype had the most firm texture when used for direct consumption. Based on the results of chemical properties, MLGAR 0034, MLGAR 0111, MLGAR 030, MLGAR 0150, MLGAR 0312, and MLGAR 0131 are classified into one cluster.

1. Introduction
Elephant foot yam (Amorphophallus campanulatus) is a tuber plant belonging to the Araceae family. Elephant foot yam is widely cultivated in Asia, Africa and the Pacific and the Caribbean Islands and it is also commonly found in Indonesia, especially growing in forest areas. Elephant foot yam has been cultivated as an intercrop plant along with ginger under coconut or banana trees in India. The production yield of the elephant foot yam is 50-80 t/ha, thus, this plant has a low rate of production and is an underutilized crop in Indonesia [1]. The production of Amorphophallus muelleri in East Java is 6-10 t/ha/year of the fresh tuber [2].

Tuber crops including food crops which occupy the third place after cereals and legumes. In the world, this plant is produced around 5.5 million tons per year and can provide around one-third of the food intake of more than 400 million people in the tropics. A. campanulatus is a type of root source of carbohydrate, but low in protein but rich in minerals including the amount of iron and calcium, as well as potassium and magnesium [3]. In Indonesia, A. campanulatus tubers are used as a source of carbohydrates and also as ingredients of traditional medicine. Recent studies have also shown that Amorphophallus campanulatus extract has anti-inflammatory properties [4], anti-microbes [5], hepatoprotective [6], and antioxidant properties in vitro [7].

A. campanulatus is a food source of carbohydrates that can be used as a substitute for rice. It is one of the local foods with relatively easy cultivation and can be used as an alternative source of...
carbohydrates. The tuber processing that is often known to the public is by steaming and boiling. Generally, Elephant foot yam tubers contain P (34 mg / 100 g), calcium (50 mg / 100 g), vitamin A (434 IU / 100 g) [8], crude protein (2.14%), fat (0.46%), calcium (32.1 mg / 100 g) and crude fiber (1.68%) [9]. Tubers also contain anti-nutritional factors, such as oxalate and phytate. The levels of oxalic acid in elephantiasis are 1.3% [10]. The nutrient composition of tuber elephants varies according to where they grow, soil, season, and water and climate situation [3].

In term of breeding activities, the diversity of elephant food yam (Amorphophallus campanulatus) in Indonesia is essential to be explored concerning its potential use for food and benefit for health. Availability of genetic resources (GR) as a source of material genetic is very important. Conservation of genetic resources was essentially maintaining the survival of species/varieties without changing their identity as long as possible and necessary to sustain the ongoing breeding activities in generating varieties with a value-added economy. Thus the gene source contained in the germplasm collection will be used at any time if needed in a continuous breeding program. Maintaining genetic identity, which is a top priority for a gene bank curator, can be achieved by storing original seeds (or from initial propagation) as a base collection in a long-term condition in sufficient quantities.

With the conservation and characterization of GRs, character control genes can be optimally and efficiently utilized and efficient through reliable information and documentation system. In one group of germplasm, assessments have a high level of similarity of quantitative and qualitative characters, so it needs characterization so that the identity of accession can be known as a support for variety protection. Potential tubers will become important commodities in the future, both as food and industrial raw materials, therefore it is important to start characterizing the potential of these commodities. Therefore, this study was performed to identify the physicochemical characteristics of 14 elephant food yam germplasm collected by Indonesian Legumes and Tuber Crops Research Institute (ILETRI).

2. Material and Methods
A total of 14 accessions of elephant food yam collection of Iletri germplasm was harvested at the optimal age. Fresh tuber samples were cut off at the base and tip part, peeled and then shredded for water content analysis. The center of the fresh tubers was cut transversely, then the color intensity was measured using a color reader. Fresh tubers were also cut into a small cube (0.5 x 0.5 x 0.5 cm), then dried in the oven for 24 hours at a temperature of 55-60°C and weighed for measuring the dry matter content. Furthermore, this dry material was finely ground (at least 70 mesh), then used as material for chemical analysis including water, ash, reducing sugar, starch, amyllose and dietary fiber content. Other physical analysis, namely the texture profile characteristics which includes adhesiveness, hardness, springiness, cohesiveness, and chewiness to steamed tubers from each accession as a sample. The study was designed using a completely randomized design and repeated three times. The data obtained were analyzed using analysis of variance and the average spread using the multiple range test method. Observations and methods carried out, including:

a. Moisture content is carried out by gravimetric method according to SNI 01-2891-1992 [11].
b. Dry matter content with the oven dried method in the oven for 24 hours at a temperature of 55-60°C
c. The color of the tubers using a Minolta color reader and values (L, a, b) were collected.
d. Texture Profile Characteristics with the TPA method as describe by Bourne using a texture analyzer [12].
e. Ash content using the furnace method (SNI 01-2891-1992) [11].
f. Starch content was carried out using the acid hydrolysis method followed by the Nelson-Somogyi method [13].
g. Amylose content spectrophotometric method [14].
h. Reducing sugar content was determined by Nelson Somogyi's method [13].
i. Dietary fiber with the enzymatic method [15].
3. Result and discussion

3.1. Moisture content, dry matter, and color of tubers Elephant Foot Yam from ILETRI germplasm collection

Elephant foot yam (Amorphophallus campanulatus) is one type of tubers that still has great potential to be explored in Indonesia. This plant usually thrives under the auspices of other plants. Elephant foot yam grows early in the dry season and at the end of the dry season, the tubers can be harvested [16]. Utilization of the tubers is generally only boiled and made flour.

Of the fourteen accessions observed, fresh tuber water content ranged from 66.58 - 88.36% (Table 1). The range of water content is quite wide, different from the results of Yadav and Singh's research [17] which reported that the water content of the tubers was 76.93 - 77.5%, while Datta reported that the tuber moisture content of 66.08% [18]. Likewise, dry matter content also has a wide range of values, namely 17.67-31.46%. Accession no 7 has the highest dry matter content that is 31.46% (Table 1).

In general, tubers of Elephant foot yam have a bright yellow to orange color. Based on observations of the level of brightness using a color reader, accession No. 7 also has the highest brightness level of 81.63, and the lowest level of brightness is found in Accession No. 4 (70.53).

Table 1. Moisture content, dry matter content, dan the color values of 14 elephant foot yam accessions from ILETRI Collections

| No. | Accessions | Moisture content (%) | Dry matter content (%) | L*  | a     | b     |
|-----|------------|----------------------|------------------------|-----|-------|-------|
| 1   | MLGAR 0034 | 66.58 j              | 29.94 b                | 79,20 e | 53,30 bcd | 45,40 def |
| 2   | MLGAR 0111 | 71.73 g              | 30.23 b                | 80,43 bc | 54,40 bc | 41,00 hi  |
| 3   | MLGAR 0303 | 72.94 f              | 28.25 d                | 77,63 fg | 56,43 b  | 44,07 efg |
| 4   | MLGAR 0150 | 72.83 f              | 29.86 b                | 70,53 h  | 59,83 a  | 42,97 fgh |
| 7   | MLGAR 0176 | 73.87 e              | 23.58 h                | 79,37 de | 55,30 bc | 47,83 bcd |
| 6   | MLGAR 0058 | 70.34 h              | 27.62 e                | 77,97 f  | 55,90 bc | 47,90 bcd |
| 7   | MLGAR 0312 | 69.43 i              | 31.46 a                | 81,63 a  | 53,73 bcd| 41,40 ghi |
| 8   | MLGAR 0131 | 70.81 h              | 29.34 c                | 80,70 b  | 54,73 bc | 39,77 i   |
| 9   | MLGAR 0129 | 88.36 a              | 17.67 j                | 76,83 g  | 53,10 cd | 50,43 ab  |
| 10  | MLGAR 0158 | 84.71 c              | 28.08 d                | 79,63 cde| 56,13 bc | 46,20 cde |
| 11  | MLGAR 0016 | 81.10 d              | 30.10 b                | 80,23 bcd| 53,27 bcd| 51,13 a   |
| 12  | MLGAR 0101 | 85.07 c              | 24.19 g                | 80,07 bcd| 54,03 bcd| 47,97 bcd |
| 13  | MLGAR 0262 | 86.38 b              | 22.08 i                | 79,60 cde| 51,17 d  | 44,77 ef  |
| 14  | MLGAR 0260 | 84.55 c              | 25.76 f                | 80,67 b  | 55,33 bc | 48,57 abc |

The number in the column followed by the same letter, is not significantly different in the LSD test level of 5%.

3.2. Texture profile characteristics of steamed tubers 14 accessions elephant food yam, ILETRI germplasm collection

The hardness value observed in the steamed tubers showed a fairly wide range with the highest value on accession 8 (38.14 N), and the lowest in accession number 11 (11.90). The level of tuber springiness also varies with the highest value seen in accession number 4 and the lowest in accession number 11. The chewiness level, which is the result of the multiplication of hardness with cohesiveness and springiness, also appears to be the highest at No. 7. The varying texture profiles between clones / varieties are related to levels of amylose, amylopectin, moisture content and reducing sugar content of tubers [19].
Table 2. Texture profiles characteristics of 14 accessions of elephant food yam tubers from ILETRI Collections

| No. | Accessions     | Adhesiveness (Ns) | Hardness (N) | Springiness (%) | Cohesiveness | Chewiness (N) |
|-----|----------------|-------------------|--------------|-----------------|--------------|---------------|
| 1   | MLGAR 0034     | 0.41              | 14.88        | 100.68          | 0.05         | 82.22         |
| 2   | MLGAR 0111     | 0.02              | 35.79        | 85.57           | 0.10         | 333.80        |
| 3   | MLGAR 0303     | 0.29              | 12.82        | 95.38           | 0.17         | 199.80        |
| 4   | MLGAR 0150     | 0.36              | 35.19        | 116.89          | 0.11         | 455.48        |
| 5   | MLGAR 0176     | 1.91              | 26.74        | 78.70           | 0.15         | 325.32        |
| 6   | MLGAR 0058     | 1.82              | 12.93        | 102.91          | 0.19         | 271.73        |
| 7   | MLGAR 0312     | 0.01              | 30.40        | 93.00           | 0.19         | 532.09        |
| 8   | MLGAR 0131     | 3.19              | 38.14        | 88.46           | 0.12         | 397.60        |
| 9   | MLGAR 0129     | 0.06              | 18.68        | 88.26           | 0.22         | 333.00        |
| 10  | MLGAR 0158     | 0.79              | 21.16        | 89.59           | 0.14         | 264.56        |
| 11  | MLGAR 0016     | 0.38              | 11.90        | 76.96           | 0.25         | 229.05        |
| 12  | MLGAR 0101     | 0.29              | 22.30        | 93.72           | 0.17         | 332.29        |
| 13  | MLGAR 0262     | 0.13              | 18.51        | 99.07           | 0.18         | 321.11        |
| 14  | MLGAR 0034     | 0.32              | 12.16        | 88.94           | 0.20         | 209.89        |

3.3. Chemical properties of 14 accessions elephant food yam, ILETRI germplasm collection

Ash content, which represents tuber mineral content (Winarno 1997), varies from 2.53% bk (accession no 7) to 4.91% bk (accession no 13) (Table 3). This value is relatively not much different from the ash content of elephant foot yam tubers from several other studies of 3.8% [20] and 3.32% by Septiani [21]. The ash content value is also almost the same as the ash content value of the eight yellow/orange sweet potato clones (2.86% -5.28% bk) [22], canna flour (2.89%), coconut sweet potato flour (3.56%), and gembili flour (2.87%) [20]. The mineral content of fresh plant material is strongly influenced by the mineral conditions of the soil where it grows.

The starch content of the tubers was significantly different between accessions with the highest value obtained in accessions no 11 (72.7% bk) and the lowest in accessions number 5, 6 and 9 (Table 3). This value is slightly lower when compared to the starch content of the research of Hasbullah and Umiyati (2017) which has a starch content value of 74.39% bk. Meanwhile, the amylose content of tubers varied from 23.84% db to 31.37% db with the highest values obtained in accession clones number 7, and the lowest in accessions 9 (Table 3). Amylose plays a role in the ability of starch to absorb water, especially in the gelatinization process. In addition, it also determines the texture of the tubers when they are cooked because the higher the amylose content, the texture of the tubers tends to be harder / denser because they are able to absorb a lot of water and hold them intact at high heating.

Table 3. Chemical properties of 14 accessions elephant food yam from ILETRI germplasm collection (% dm)

| No.  | Accessions     | Ash   | Starch   | Amylose  | Red. Sugar | Dietary fibre |
|------|----------------|-------|----------|----------|------------|---------------|
| 1    | MLGAR 0034     | 3.69 e| 59.88 fg | 26.28 de | 2.75 d     | 33.47 jk      |
| 2    | MLGAR 0111     | 3.37 h| 60.33 fg | 29.44 b  | 2.90 c     | 34.80 hi      |
| 3    | MLGAR 0303     | 3.81 d| 58.64 g  | 26.63 cd | 1.46 g     | 41.35 e       |
| 4    | MLGAR 0150     | 3.48 g| 58.53 g  | 27.13 cd | 2.21 f     | 37.03 f       |
| 5    | MLGAR 0176     | 3.79 d| 53.21 h  | 25.56 ef | 2.57 e     | 35.23 gh      |
| 6    | MLGAR 0058     | 3.50 fg| 53.70 h  | 25.20 f  | 1.00 i     | 31.90 l       |
| 7    | MLGAR 0312     | 2.53 j| 63.98 de | 31.37 a  | 2.92 c     | 32.21 kl      |
The number in the column followed by the same letter, is not significantly different in the LSD test level of 5%
db = dry base

For reducing sugar, ranged from 1.42-7.89% wk with the highest value in accession number 13 (Table 3). The results of previous research reported that the reducing sugar level of Elephant food yam was 1.94% bk [23]. Although these elephant food yam tubers have almost the same color or the same as yellow to orange sweet potato, however, their reduced sugar content is still relatively low when compared to sweet potato with yellow or orange tuber.

Dietary fiber is an important component in the body's digestive system. The presence of dietary fiber, digestion efficiency is increased while helping to reduce components that are detrimental to its nutritional value. Elephant food yam has dietary fiber which turns out to be capable and beneficial in terms of health and medicine. The range of dietary fiber content of the 14 accessions tested ranged from 31.90-54.29%. The lowest content of 31.90% was found at accession no. 6 and the highest was in accession number 12.

![Cluster of 14 elephant foot yam germplasm based on the chemical composition.](image1.png)

**Figure 1.** Cluster of 14 elephant foot yam germplasm based on the chemical composition.

Based on the chemical composition (moisture, ash, starch amylose, reducing sugar, and dietary fiber), 14 elephant food yam genotypes were grouped into five clusters at 75% of similarity (Figure 1). Cluster 1 consisted of six genotypes, three, two, and two genotypes were found in cluster 5, cluster 2 and cluster 4, respectively, while only one genotype belonged to cluster 3. The differences between clusters were seen particularly for moisture, starch, amylose, reducing sugar, and dietary fiber.
contents. The genotype in cluster 3 considerably had high moisture and reducing sugar contents, while the starch and amylose contents were low. Cluster 5 composed of genotypes with high moisture and dietary fiber contents. This information would be useful for selection of elephant food yam genotypes as breeding materials for particular trait.

4. Conclusion
The diversity of elephant food yam (Amorphophallus campanulatus) in Indonesia is essential to be explored concerning its potential use for food and benefits for health. Breeding for release new varieties with specific characters needs a variety of genetic materials, including germplasm. The physical observations showed that the colour of the flesh varied from yellow to orange with the lightness values (L*) ranging from 70.53 to 81.63. The moisture, ash, reducing sugar, and amylose contents also varied from 66.58 – 88.36%, 2.49-4.91% (dm), 1.42-7.89 % (dm), 23.84-31.37 % (dm), respectively. The highest starch content (72.7 % dm) was seen in MLGAR 0016 genotype, followed by MLGAR 0158 (70.79% dm), and MLGAR 0101 (67.82% dm). These elephant food yam genotypes particularly contained high dietary fiber with the highest value observed in MLGAR 0101 (54.29% dm) and MLGAR 0016 (53.15% dm). Two genotypes, namely MLGAR 0016 and MLGAR 0101 were promising as breeding materials for high starch and dietary fiber purposes. The hardness levels of the boiled tubers ranged from 11.90-38.1 N with the highest value observed in MLGAR 0131 N, suggesting that this genotype had the most firm texture when used for direct consumption. Based on the results of the observations made, one cluster can be decided based on the analysis of chemical properties carried out, the accessions that have chemical properties that are classified into one cluster are MLGAR 0034, MLGAR 0111, MLGAR 030, MLGAR 0150, MLGAR 0312, and MLGAR 0131.

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